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AgRISTARS

A Joint Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing

September 30, 1981

NATIONWIDE FORESTRY APPLICATIONS PROGRAM

Renewable Resources Inventory Project

Final Report

Data Base Manipulation for Assessment of Multiresource Suitability and Land Change

USDA, Forest Service
Contract No. 53-3187-1-38

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16. Abstract

Progress is reported in three tasks which support the overall objectives of Task 4 (Renewable Resources Inventory) of the AgRISTARS program. In the first task, the geometric correction algorithms of the Master Data Processor were investigated to determine the utility of data corrected by this processor for Forest Service uses.

The second task involved investigation of logic to form blobs as a precursor step to automatic change detection involving two dates of Landsat data. Some routine procedures for selecting BLOB parameters were developed.

In the third task, a major effort was made to develop land suitability modeling approaches for timber, grazing, and wildlife habitat in support of resource planning efforts on the San Juan National Forest.

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INTRODUCTION AND SUMMARY

This report discusses work performed on contract 53-3187-1-38 during the period February to September 1981. The work discussed here is part of a five-year program between the U.S. Forest Service and ERIM to develop, test, and transfer to the Forest Service advanced Landsat computer data processing algorithms. The efforts conducted by ERIM are part of the AgRISTARS program, Renewable Resources Inventory Project which is administered by the Nationwide Forestry Applications Program. AgRISTARS is a joint program of the U.S. Department of Agriculture, the National Aeronautics and Space Administration, the Department of Commerce, the Agency for International Development, and the Department of the Interior.

1.1 OVERALL FOREST SERVICE GOALS

Pressures are mounting for the Forest Service to produce greater amounts of timber, while maintaining recreation and wildlife habitat on National Forests, and at the same time continue compliance with National environmental legislation. The resolution of these increasingly conflicting requirements will require a greater intensity and sophistication of forest management. One way to improve the efficiency of forest management is to organize existing information in a computer geographic data base and <u>also</u> provide manipulative computer models which can rapidly evaluate management alternatives. Information used for planning comes from a variety of sources -- map overlays, aerial photography and satellite imagery, digital terrain data, and field observations. The one thread which ties all these types of information together is a common geographic reference system. If aerial photography and satellite data are to be of use to the Forest Service, the information resulting from the analysis of that data must be put into registration with map overlay data. Techniques to do that exist and are in the process of being transferred to the Forest Service.

Further efficiencies in planning will result from improvements in the conduct of periodic resource surveys. Currently, Congress mandates periodic surveys of forest resources, at five or ten year intervals. Resources are inventoried by a sampling strategy intended to provide statistically significant information on a forest level or state level. Because most resources change slowly, considerable economy of field investigation could result from a survey of only those remaining areas which have changed significantly. Change can occur in a variety of ways -- some of which the Forest Service is aware of and other of which it is not. More importantly, changes in land cover in areas surrounding National Forests <u>can</u> influence management strategies. Thus more effective management will require knowledge of what is happening outside the National Forest as well as what is happening in the Forest. Comprehensive change detection and identification techniques become more important as planning activity intensifies.

1.2 ERIM CONTRACT OBJECTIVES

Since 1975, ERIM has been working under funding from the U.S. Forest Service to help solve resource management problems on National Forests. Early efforts in 1975-76 concentrated on the assessment of the classification accuracy of forest cover classes obtainable with remotely sensed data of varying degrees of spatial resolution. The test area for the study was the Sam Houston National Forest in Texas.

After a funding hiatus, work began again in 1978. For the 1978-79 period, ERIM further developed precision Landsat geometric correction software and adapted spatial averaging (BLOB) and change vector analysis (CVA) techniques (originally developed under NASA funding) to estimating changes in forest cover between 1972 and 1975 on the Palouse District of the Clearwater National Forest in Idaho. The Landsat geometric correction software was transferred to the Forest Service Ft. Collins Computer Center.

Focus of the 1979-80 work was Kershaw County, South Carolina. At this stage of the development of change detection techniques, it became clear that automatic change detection procedures showed considerable promise and that, furthermore, Geographic Information System technology could help the Forest Service meet new management objectives. Accordingly, ERIM prepared a five year work plan showing how these technologies could be tested, refined and transferred to the Forest Service. The Kershaw County work, focussed on refinement of automatic change detection and identification procedures, was the first phase of work under the five year plan.

In 1980-81, still in keeping with the plan, efforts shifted to San Juan National Forest in Colorado. The purpose of shifting the test site was to evaluate the change detection procedures, refined by the experience in Kershaw County, in a different forest environment. Also, we began refinement of existing Geographic Information System techniques for eventual transfer to the Forest Service. Those results are reported in detail in this report.

ERIM remains convinced that change detection and identification and Geographic Information System technology, although originally developed by DoD and other federal agencies, can play an important role in future Forest Service resource management efforts. Although recent funding levels for this type of work have been declining and appear to be in some jeopardy, we continue to remain optimistic that these technologies, when transferred to the Forest Service and integrated into the overall planning process, will improve efficiency and productivity of forest managers. With that hope in mind, the plans for future work will focus on advanced development and quasi-operational testing of these technologies in a realistic planning environment. The test site will probably be the Clearwater National Forest in Idaho.

With the completion of the current contract effort, we feel that ERIM's geometric correction software is ready for use by the Forest

Service. The recommended mode of deployment is in a centralized facility. Change detection procedures involving first spatial averaging followed by change detection continue to be developed. New effort was begun this year on the development of modeling procedures to objectively estimate land suitability for a variety of uses. The focal point for the present contract is in the San Juan National Forest in southwest Colorado.

1.3 LANDSAT SYSTEM

Landsat data has been collected continuously since the first satellite was launched in 1972 as an Earth Resources Technology Satellite (ERTS). Landsat 1, 2, and 3 were launched, respectively July 23, 1972, January 22, 1975, and March 6, 1978. Landsat-1 ceased operation January 1978 after more than five years of operation, greatly exceeding its one year design life. Each satellite is in a near polar and sun-synchronous orbit at about 900 kilometers altitude. Such placement permits repetitive coverage of the same location, at the same solar azimuth angle, every 18 days by each satellite. With two satellites data has been acquired for the same localities at intervals as short as nine days. The satellites pass over the earth at about 9:30-10:30 AM, local solar time.

The two Landsat imaging sensors are the Multispectral Scanner (MSS) and Return Beam Vidicon cameras (RBV). The MSS is most often utilized. A multispectral scanner image is produced by an oscillating mirror scanning the ground from west to east creating scan lines of data as the satellite passes from north to south adding lines to create the image. The MSS scans a continuous swath on the ground 185.2 kilometers (100 nm) wide. During later processing this swath is sectioned into 185.2 km by 185.2 km images or Landsat "scenes". MSS data are collected in four spectral bands, two bands sensitive to green and red light, with two bands sensitive to infrared radiation. As the scan is made energy incident on the detectors is sampled at such a rate that each sample or picture element, "pixel", measures about 56 meters in the scan direction and 79 meters perpendicular to the scan. Each pixel at this size covers an area of the ground of 0.45 hectares or 1.1 acres. Each Landsat scene includes about 7.5 million pixels.

Data are transmitted in digital form from the satellite and are processed into images or digital tapes by NASA. The data are available from the EROS Data Center, Sioux Falls, South Dakota.

1.4 SUMMARY OF CONCLUSIONS

With the investigation of Landsat geometric correction as performed by GSFC and now EROS Data Center, the further development of automatic change detection and identification procedures and the demonstration of the value of Geographic Information System (GIS) technology, we feel that we have substantially advanced the state of the art of these techniques to the point where some quasi-operational tests are in order.

In particular, the geometric correction of Landsat data as performed by NASA results in data in a projection not readily compatible with other forms of data. Therefore, the Forest Service should either try to influence NASA to provide data in UTM coordinates and/or develop, internal to the Forest Service, a geometric correction capability.

Change detection and GIS methodologies as demonstrated on the San Juan National Forest, are developed to a point where a quasi-operational test is in order. The Clearwater National Forest probably offers the most synergistic test site.

1.4.1 GEOMETRIC CORRECTION

We see two difficulties with the use of geometrically corrected data currently produced by the GSFC Master Data Processor. First, the Hotine Oblique Mercator projection into which the data are sampled is not documented well enough to permit conversion of the data into UTM or other projections in which the Forest Service has data. The data are geometrically consistent, however, as is shown in Table 1. The fact that ERIM geometric correction procedures can reduce residual errors to about 60 m rms (circular error) indicates that with proper parameters the HOM to UTM model can give acceptable conversion accuracy. The 60 m error is probably residual error in the geometric correction process.

TABLE 1

LANDSAT P DATA GEOMETRIC CONSISTENCY

	E-W Residual Errors (m)	N-S Residual Errors (m)
HOM Projection	4091.1	3306.4
GSFC Modified HOM	1834.7	1765.2
ERIM Model of HOM	49.3	43.1

The second difficulty with the GSFC corrected data is that the data resampling algorithm, cubic convolution, smears the data. There are better methods for resampling the data to a more faithful representation of the scene radiance distribution.

The ERIM geometric correction software package, which was delivered to the Forest Service two years ago, overcomes these two difficulties by correcting Landsat data to UTM coordinates and by using two-dimensional deconvolution as the resampling technique. In view of this, we recommend that the Forest Service use this geometric correction software in a central facility to produce geometrically corrected Landsat data for use on its projects. At the same time, the Forest Service should continue to make its needs known to NASA, NOAA, and EROS Data Center officials with the hope of influencing future ground processing systems.

1.4.2 CHANGE DETECTION

The change detection procedures which ERIM is implementing rely on two processing steps applied to a two-date Landsat image that has been precisely geometrically corrected and overlaid. In the first step, spatial averaging is done by an algorithm called BLOB, to reduce the variations in the data by calculating mean values over all pixels in the BLOB. Blobs must be formed to aggregate over pixels with similar color on the two dates while preserving all the important color boundaries in the data. The choice of parameters and the logic for forming blobs must be routinized if this procedure is to be operationally useful. This year we discovered through experiment on the Kershaw County data set that the blob forming logic which we have been using is as good as any alternative. The present logic combines spectral and spatial distance measures into one equation to decide if a new blob must be formed. The spectral variances which are used in the BLOB algorithm may be estimated from the variances in the signatures of important scene classes. The setting of spatial variance parameters in BLOB will depend on the spatial distribution of scene radiance, and analysis procedures for estimating those numbers have not yet been developed.

The second step in the change detection procedure is change vector analysis (CVA), wherein the Brightness and Greenness (Kauth and Thomas, 1976) changes between the two days are analyzed to determine if changes have occurred, and if so to gain some understanding of the type of change. We continue to expect that stratification of the scene will be important in analyzing the types of change. Data normalization to account for changes in sun angle and atmospheric conditions will also be necessary.

1.4.3 LAND SUITABILITY ANALYSIS

A major effort this year was the development of land suitability models and assessment procedures using geographic information systems. Conversations with San Juan National Forest personnel revealed that timber, grazing, and wildlife habitat were major concerns. Consequently, a geographic data base of land cover (derived from Landsat data), topographic data, and digitized road network data was assembled for the Rampart Hills quadrangle. The data base consists of the above data in 50 m cells oriented along UTM coordinates. Preliminary suitability maps for timber harvest and elk habitat have been produced by manipulating the data base. Most of the manipulative procedures have been developed in ERIM's Earth Resources Data Center to be compatible with the Remote Analysis Station (RAS). Using RAS, an investigator in the San Juan National Forest can call up a central computer and manipulate data while observing the results on a color display.

2
INVESTIGATION OF GEOMETRIC CORRECTION OF LANDSAT DATA

2.1 OVERALL PROGRAM GOALS AND HISTORY

ERIM's involvement with remote sensing for the U.S. Forest Service dates back to the early 1960's, when aircraft multispectral scanner (MSS) data were collected and processed to attempt to previsually detect insect infestations in the Black Hills and to map forest and rangeland resources in Colorado. ERIM has, under NASA SR&T funding for the Forestry Applications Program, also conducted programs to analyze the effects of spatial resolution on the discriminability of forest categories in airborne MSS data. Later in that same program, multispectral data processing techniques were investigated which compensated for terrain slope and aspect variations and which attempted to extract forest canopy component information. The empirical studies were supported by modeling efforts.

Because of the interest of the Forest Service in the increased operational use of remote sensing in support of legislatively-mandated multiresource inventories, a program was devised to transfer Landsat geometric correction software to the Forest Service through a single computer system license. This was carried out in 1979 under the Nationwide Forestry Applications Project. Work also began on change detection algorithms and continued the following year under the AgRISTARS program. We continue to develop, test, and transfer to the Forest Service advanced Landsat computer processing algorithms for change detection. These algorithms are intended to improve the efficiency of the Forest Service inventory process by providing interim update information between recurrent surveys through the identification of areas which have changed between two observations.

Now that the technical developments in Landsat processing and information processing are maturing, the Forest Service must decide how to make the best use of these developments. The Forest Service already has a broad variety of information that is recorded on map overlays in a variety of map projections. Much of this information is recorded with a degree of geometric accuracy not typically matched by Landsat data. Integrating these two sources of data requires that Landsat data be corrected to meet map accuracy standards.

When the Forest Service acquired geometric correction capabilities from ERIM two years ago, it was not clear how accurate the geometrically corrected Landsat scenes produced by Goddard Space Flight Center (GSFC), and distributed through EROS Data Center, would be. This report describes an investigation of the geometric correction procedure implemented by GSFC.

On a broader scale, if these efforts mark the beginning of a Geographic Information System for use with Forest Service information, there must be careful consideration of logistical, financial, and institutional arrangements needed to accomplish this. If GSFC geometric processing is acceptable, can the quantity and timeliness of the data be assured through standard or specialized arrangements? If specialized arrangements are needed, what costs and other requirements are there? Can other Forest Service data be related to data corrected by GSFC? What would it cost to implement the geometric correction capabilities that the Forest Service has? Does the size and location of this capability affect its cost, quality, flexibility, or practicality? Are alternatives available that can reduce costs or increase quality or flexibility?

The preliminary design of a Geographic Information System must be done carefully so as to preclude the fewest avenues to improving it. Experience can alter many initial impressions and a well-designed information system will be able to change to take advantage of that experience. The answers to some of the questions posed above will be important guidelines in the development of a Geographic Information System.

2.2 GODDARD CORRECTION OF P-FORMAT DATA

The P-format tape produced by Goddard provides a Landsat scene in a geometrically corrected format. Geometrically corrected data is available only for those path-row locations where a ground control reference scene has been produced. Subsequent scenes are geometrically corrected by scene-to-scene registration with the ground reference scene. The geometric accuracy of the resulting scenes is based on the geometric accuracy of the ground reference scene and on the accuracy of the scene-to-scene registration process.

Learning about the geometric correction process proved to be a difficult task. The processing of reference scenes was completed a few years ago. The methods were not documented and the people who processed the imagery were not available to describe the techniques they had used, so this investigation was limited to discussions with people who had second or third hand knowledge of the system.

Two approaches were used to evaluate the accuracy of the ground reference scene. The first approach attempted to duplicate the processing used to transform the original scene into the ground reference scene, but sketchy information impeded this approach. The second approach involved selecting image control points and comparing the residual errors between their map derived HOM coordinates and the image derived HOM coordinates.

2.2.1 GROUND REFERENCE SCENE PROCESSING

The GSFC procedure for creating a reference scene:

(1) selects ground control points,
(2) calculates warping factors, and
(3) resamples the original scene using warping factors.

Steps two and three are defined by computer software, but there is very little information other than that available. Discussions with Mr. Bernard Peavey (1981) revealed some of the details of the ground control point selection (Step one). But this area is not well documented and several details are still unclear.

The ground control points were selected using an image display CRT, a zoom transfer scope, and 1:24,000 scale maps where available. For a given scene, a large scale Landsat data transparency was used to identify a group of features distributed throughout the scene. These features were selected using criteria that placed emphasis on land-water boundaries (because of their high contrast), as well as other features that were unlikely to move or to change contrast. Once identified, these featurues were located on the maps and recorded by placing a mark near the feature so as to avoid confusion with map symbols. The latitude and longitude coordinates of the mark were recorded from the map for later entry into the ground control point library.

Subsequently, for each point the map was placed under a zoom transfer scope which had been modified. By removing the print easel and placing a CRT display directly behind the zoom transfer scope, the screen was positioned in the same field of view that the print easel formerly occupied. The zoom scope and the map were manipulated until the map features near the map control point aligned with the features in the portion of the reference scene image displayed on the CRT. A cursor was moved to the position on the screen that coincided with the map control point mark previously placed on the map. The line and pixel coordinates of the image control point were recorded for entry into the ground control point library.

Entries in the ground control point library consist of a portion of a scene (called a chip) that is 32 pixels square. It is centered near the image control point contained in the chip. The latitude and longitude values for the chip represent the location of the map control point. However, the line and pixel values given are displacements from the upper left corner of the chip, not the displacements from the upper left corner of the scene. The latter values are needed to compute the positions of the image control points in relation to one another and in turn, the warping factors necessary to geometrically correct the scene.

Although this information is not routinely available, we obtained for our study the scene-origin-relative coordinates for the image control points for the reference scene 2189-15352, Path 21, Row 31, in the vicinity of Toledo, Ohio. Our intent was to duplicate the method used to generate these values to verify the accuracy of the image control points.

Using the equipment and methods described in the preceeding paragraphs, scene 2189-15352 of the Toledo area was analyzed. Twenty-two map control points were plotted on 1:24,000 scale maps. A digitizing and interpolation program was run to check these points which showed that they were routinely plotted within 10 meters of the latitude and longitude given in the control point library. Using the zoom scope-CRT apparatus, the corresponding image locations were identified for each control point and the line and pixel locations were recorded.

Features most often chosen as control points were freeways where they intersected with other roads and man-made water bodies. Some natural water bodies that were unlikely to change and distinctive bends in a road were also selected. The features selected look to be stable control points and have generally good boundary definition. They are too large for use in a system that relies on identification of a single pixel as the control point (such as the ERIM system) but they should be adequate for the area correlation method used by GSFC.

The line values of the image control points agreed with the ground control point library values to within .368 pixels on average. Comparison of the observed pixel values with the library pixel values showed major discrepancies of 6 to 70 pixels. The differences between the values was closely related to the distance from the first pixel in the line. A discussion with Mr. Gerald Grebowsky (1981) uncovered some of the reasons for the discrepancies but did not reduce the differences a significant amount. Grebowsky stated that the line and pixel coordinates obtained for the Toledo scene are not measurements in raw Landsat data space. Rather, a hybrid space is created where the pixel coordinates are adjusted for:

(1) line length standardization at 3200 pixels,
(2) mirror velocity profile,
(3) earth rotation,
(4) detector offsets, and
(5) other "high frequency effects".

To directly compare the ground control point library values with the observations taken from raw Landsat data, items (1) and (2) were backed out of the image control point pixel values. The other effects were not backed out because they were not documented in enough detail nor communicated to current GSFC personnel.

A conversation with Mr. Ken Crouse (1981) disclosed that the source listings of the computer programs for geometric correction amount to more than 400 pages. In general, source listings are a poor guide to understanding the functions that a program carries out. In this case trying to discern the geometric correction methods from the programs would have been nearly impossible given the volume of the listings, so the source listings were not acquired.

Figure 1 summarizes for each image control point the values given by the ground control point library, the values observed with the CRT zoom scope apparatus, the library coordinates after removing line length and mirror velocity adjustments, and the differences between the observed values and the adjusted library coordinates. The average pixel difference is 8.1 pixels or 462 meters for 57 meter pixels. The average line difference is .368 pixels or 21 meters. Whereas line errors appear

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Control Point	Map Name	Ground Control Point Library Coordinates		Observed Coordinates		Library Coordinates with Adjustments		Difference from Adjusted Library Coordinates	
		Line	Pixel	Line	Pixel	Line	Pixel	Line	Pixel
1	Wellington	1915.4050	3027.3911	1916.0000	3085.0000	1915.4050	3063.9407	0.5950	21.0555
2	Lorain	1556.1150	3004.8999	1556.0000	3065.0000	1556.1150	3041.7749	-0.1150	23.2251
3	Rossford	1654.1160	918.4410	1653.0000	940.0000	1654.1160	932.9103	-1.1160	7.0897
4	Whitehouse	1658.6689	587.3540	1658.0000	602.0000	1658.6689	599.0210	-0.6689	2.9790
5	Wightmans Grove	1790.3090	1695.2910	1790.0000	1730.0000	1790.3090	1721.4623	-0.3090	8.5377
6	Alvada	2235.3091	1332.3409	2236.0000	1360.0000	2235.3091	1352.6340	0.6909	7.3660
7	Dundee	1120.8870	587.7850	1121.0000	598.0000	1120.8870	599.2799	0.1130	-1.2799
8	Rockwood	866.4260	1137.8190	867.0000	1161.0000	866.4260	1155.0087	0.5740	5.9913
9	Hamburg	510.2600	119.3260	510.0000	126.0000	510.2600	131.0243	-0.2600	-5.0243
10	Highland Park	306.3440	1146.3730	307.0000	1170.0000	306.3440	1163.6017	0.6560	6.3983
11	Kent Lake	386.0000	220.0000	386.0000	227.0000	386.0000	230.9979	0.0000	-3.9979
12	Grosse Point	246.0000	1374.0000	245.0000	1402.0000	246.0000	1394.8013	-1.0000	7.1987
13	Chatam West	260.0000	2173.0000	262.0000	2221.0000	260.0000	2212.6431	2.0000	8.3569
14	Chatam East	179.0000	2646.0000	179.0000	2696.0000	179.0000	2683.8528	0.0000	12.1472
15	Norwalk	1890.0000	2491.0000	1890.0000	2540.0000	1890.0000	2527.4265	0.0000	12.5735
16	Jerry City	1955.0000	961.0000	1955.0000	983.0000	1955.0000	976.0322	0.0000	6.9678
17	Malinta	2015.0000	349.0000	2015.0000	359.0000	2015.0000	360.3170	0.0000	-1.3170
18	Essex West	643.0000	1584.0000	643.0000	1617.0000	643.0000	1608.3359	0.0000	8.6641
19	Essex East	829.0000	2191.0000	829.0000	2239.0000	829.0000	2224.6836	0.0000	14.3164
20	Pelee Island	1120.0000	2085.0000	1120.0000	2127.0000	1120.0000	2117.2300	0.0000	9.7700
21	Castalia	1631.0000	2036.0000	1631.0000	2077.0000	1631.0000	2067.4666	0.0000	9.5334
22	Erie	1302.0000	929.0000	1302.0000	950.0000	1302.0000	943.5170	0.0000	6.4830

FIGURE 1. COMPARISON OF GROUND CONTROL POINTS

randomly distributed around 0, most of the pixel errors are positive, strongly suggesting that the effect of adjustments 3 to 5 mentioned above is not negligible.

The average pixel difference of about 8 pixels includes at least two sources of error. The repeatability of selecting image control points would account for a portion of this difference, but should not be any larger than the average line difference (.368 pixels). So the major portion of the 8 pixel difference is likely an incomplete understanding of the process used by GSFC to transform pixel coordinate observations into the pixel coordinates recorded in the ground control point library. This transformation represents the definition of an intermediate or hybrid measurement space. An understanding of this transformation is crucial to making an analysis of the accuracy of the ground control points, and ultimately to making use of them in a geometric correction process. To date, this transformation has not been documented and our discussions with GSFC staff disclosed only parts of the transformation. Since the current staff did not originate this process, they may not be aware of some of the details.

Assessing the pixel location accuracy of image control points will require more analysis. This analysis will probably consist of obtaining a copy of the source code for geometric correction software and analyzing it -- a tedious job. Before this is undertaken, a decision should be made as to the utility of the ground image control point library currently being used by GSFC.

2.2.2 ANALYSIS OF HOM PROJECTION SCENE

Another way of evaluating the GSFC geometric correction process entails selecting image control points from a corrected scene, deriving the HOM projection coordinates and comparing them to HOM coordinates derived from the map location of the control points. This will point out any errors made in the geometric correction process although it won't identify the source of the errors (which could be inaccurate ground control points, an inaccurate reference scene, or an inadequate correction algorithm).

The ERIM model approach to geometric correction as it was modified to deal with the HOM projection can partition the errors so that systematic patterns of error can be discerned in the error plots. If a plausible explanation can be related to a systematic pattern of errors, a suitable correction factor can be introduced to remove the errors.

A ground control corrected scene of the Toledo, Ohio area taken on July 18, 1979 was evaluated. The scene is identified as frame 30500-15352, path 21, row 31.

The purpose of the test was to compare the UTM coordinates of the image control points, calculated from the control point locations in line, pixel space, using the characteristics of the Hotine Oblique Mercator projection as documented in the Landsat Data Users Handbook (EROS Data Center, 1978) and the Hotine-UTM conversion capability of the program supplied by EROS Data Center. The UTM coordinates of the control points were determined from 1:24,000 scale topographic maps. Image control points were located by visual inspection on the color interactive display in ERDC.

The calculated UTM coordinates of the image control points were compared with the map control points and patterns of residual errors were plotted. Also, rms errors in the north-south and east-west directions were calculated. To the extent that the scene has been accurately corrected, the HOM projection derived positions of the image control points will agree with the derived HOM positions of map control points and the residual errors will be small.

Figures 2 and 3 show the pattern of east-west and north-south errors plotted as a function of east-west position within the scene. In the diagrams, the eastern edge of the scene is at the bottom and the western edge at the top. Each vertical line represents 2,000 meters

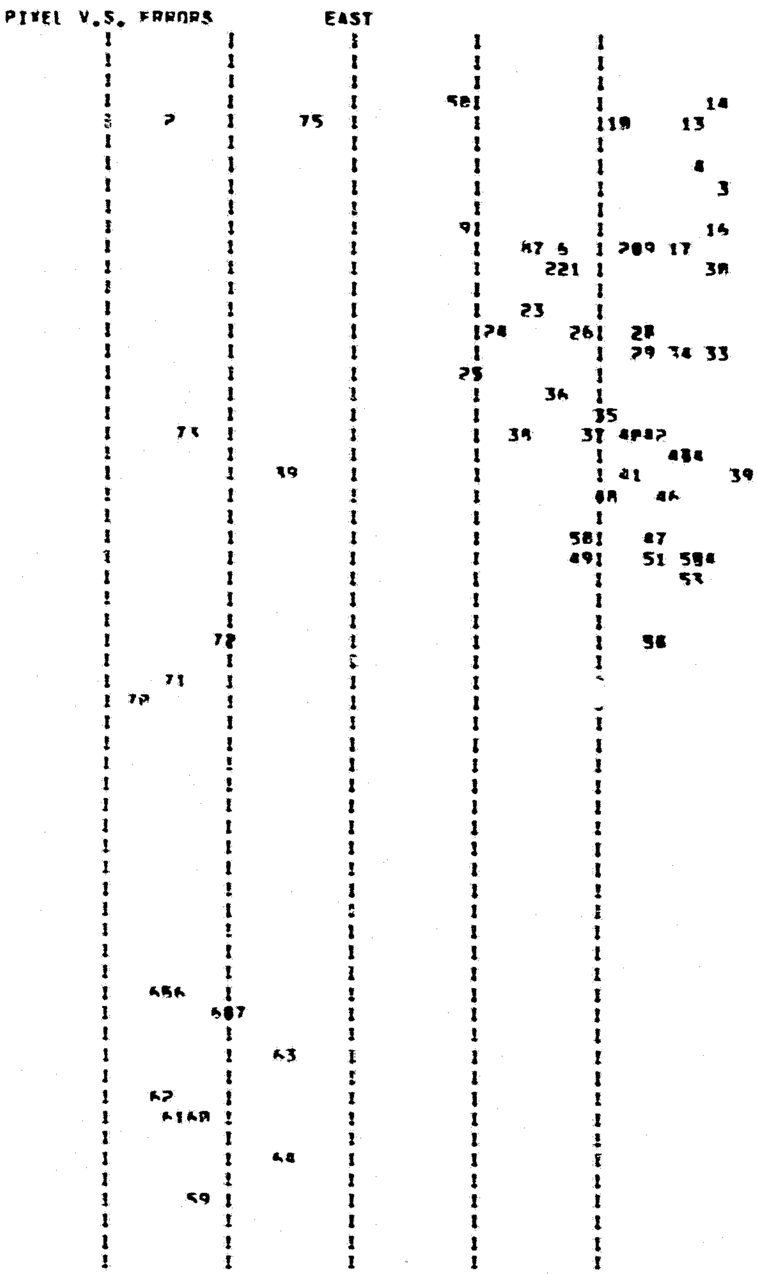

FIGURE 2. EAST-WEST ERRORS IN DOCUMENTED HOM PROJECTION VERSUS EAST-WEST POSITION

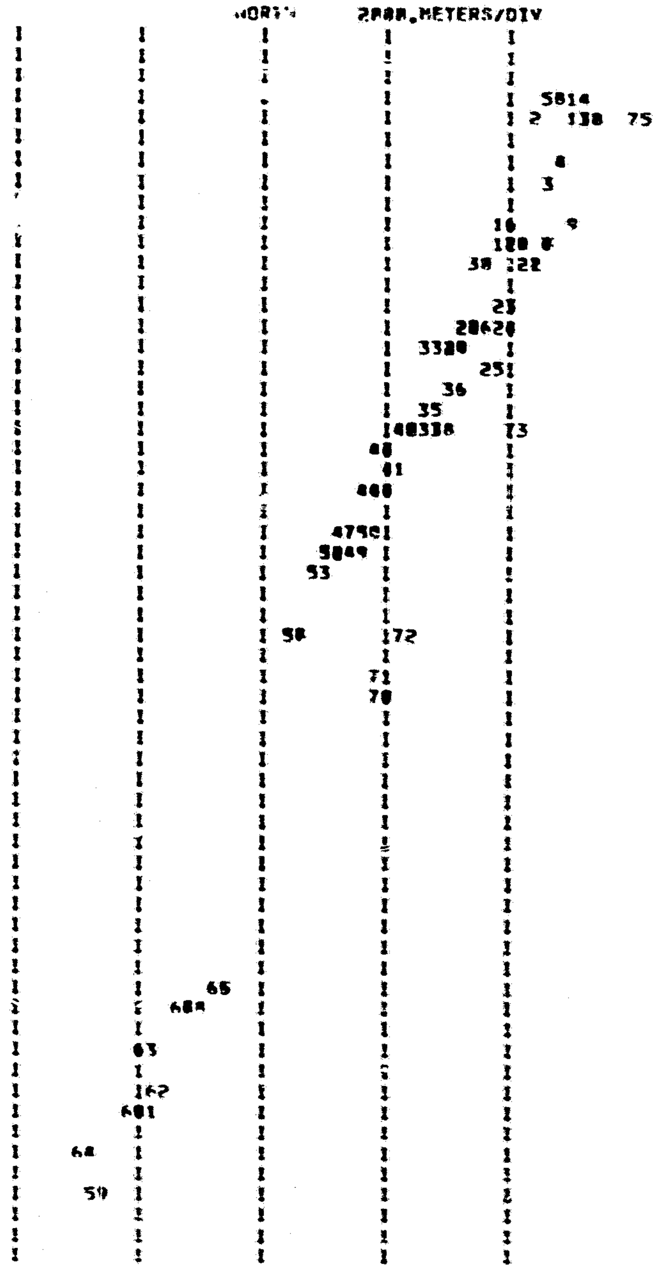

FIGURE 3. NORTH-SOUTH ERRORS IN DOCUMENTED HOM PROJECTION VERSUS EAST-WEST POSITION

error from the true location, portrayed by the center line. Figures 4 and 5 show the pattern of east-west and north-south errors plotted as a function of north-south position within the scene, with the north at the top of the figure and the south at the bottom. The rms errors in the east-west direction were 4091.1 meters and 3306.4 meters in the north-south direction. Figure 3 shows a systematic pattern which was a result of large yaw error. The definition of the HOM projection was assumed to contain all the parameters needed to relate the image control points to the map control points. Discussions with Goddard personnel disclosed that this was not true. A processing step designed to conserve computer memory space accounts for a portion of the yaw error. To minimize computer memory use, the axis of the HOM projection was rotated through an angle which aligns the scan lines as nearly as possible with normals to the projection axis. This angle is different for each scene processed.

The ERIM-HOM model was adjusted to accommodate the rotation. Figures 6, 7, 8, and 9 show error plots of the scene after reprocessing. The total errors were cut in half; rms east-west errors were 1834.7 meters; rms north-south errors were 1765.2 meters. The plot intervals again represent 2000 meters. Figure 7 shows that large yaw errors remain.

2.3 ERIM CORRECTION OF LANDSAT DATA

2.3.1 P-FORMAT DATA

Both of the above cases show that scenes produced by the GSFC geometric correction process leave room for improvement when compared to the documented HOM Projection or when compared to the modified HOM projection that GSFC has defined. Because nearly two years of Landsat data are archived in this way, more accurate geometric processing methods are needed. The ERIM model for correcting raw Landsat data estimates parameters that relate raw data to a map projection. In a similar fashion, the model used for this correction effort was altered to

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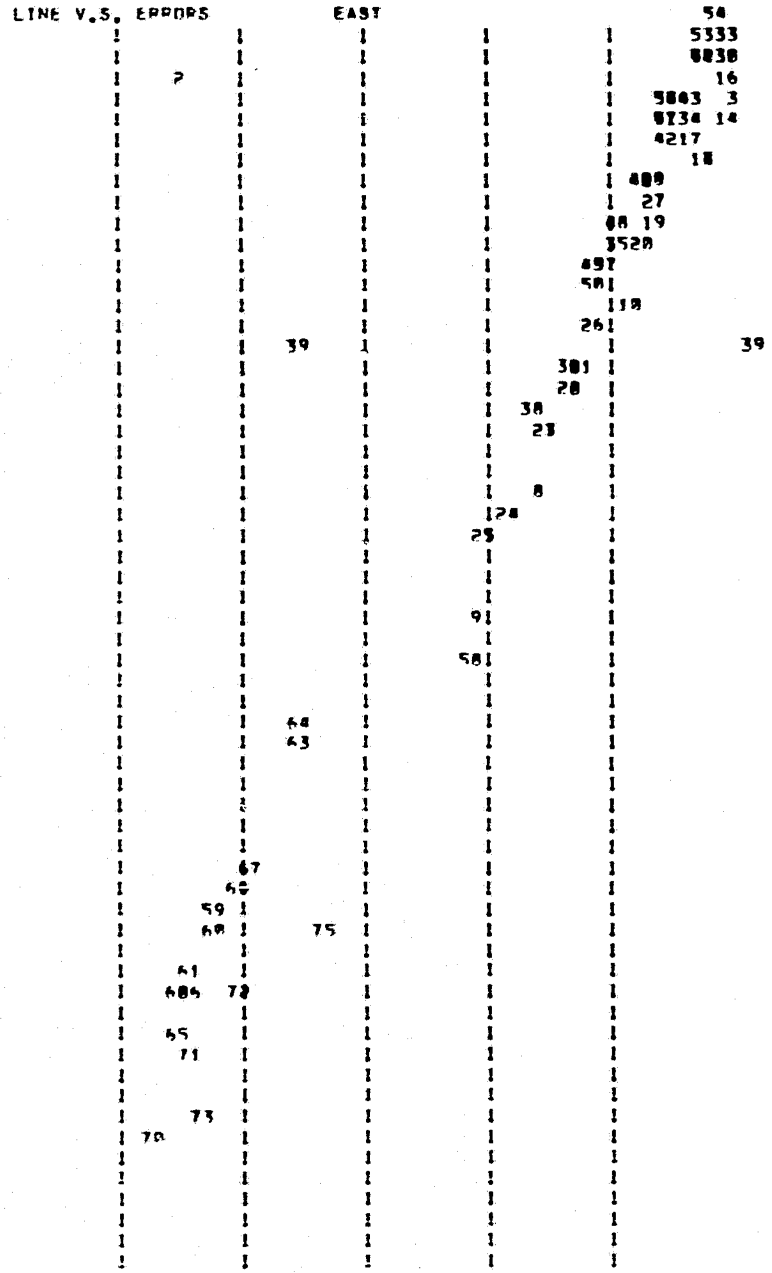

FIGURE 4. EAST-WEST ERRORS IN DOCUMENTED HOM PROJECTION VERSUS NORTH-SOUTH POSITION

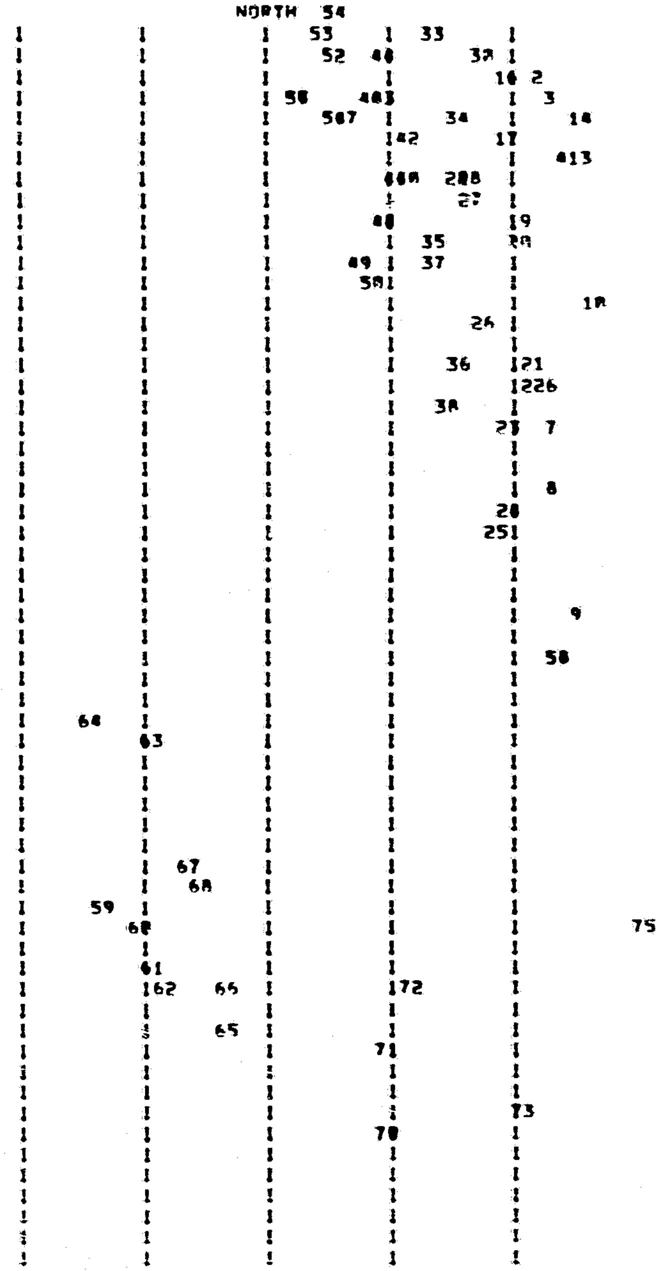

FIGURE 5. NORTH-SOUTH ERRORS IN DOCUMENTED HOM PROJECTION VERSUS NORTH-SOUTH POSITION

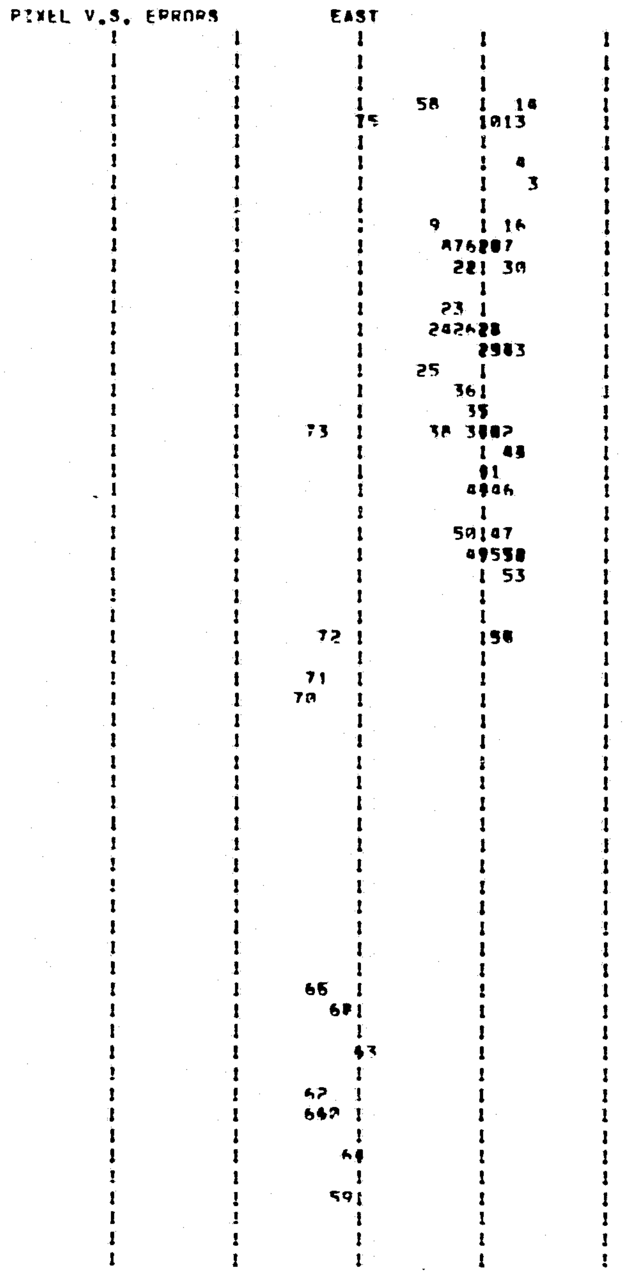

FIGURE 6. EAST-WEST ERRORS VERSUS EAST-WEST POSITION AFTER HOM ROTATION

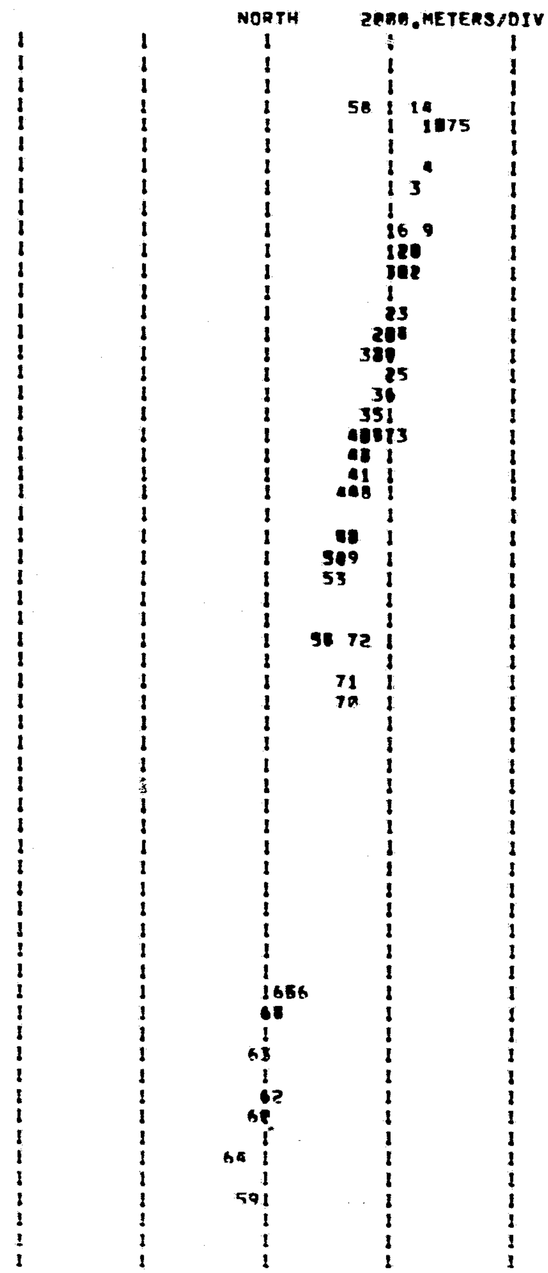

FIGURE 7. NORTH-SOUTH ERRORS VERSUS EAST-WEST POSITION AFTER HOM ROTATION

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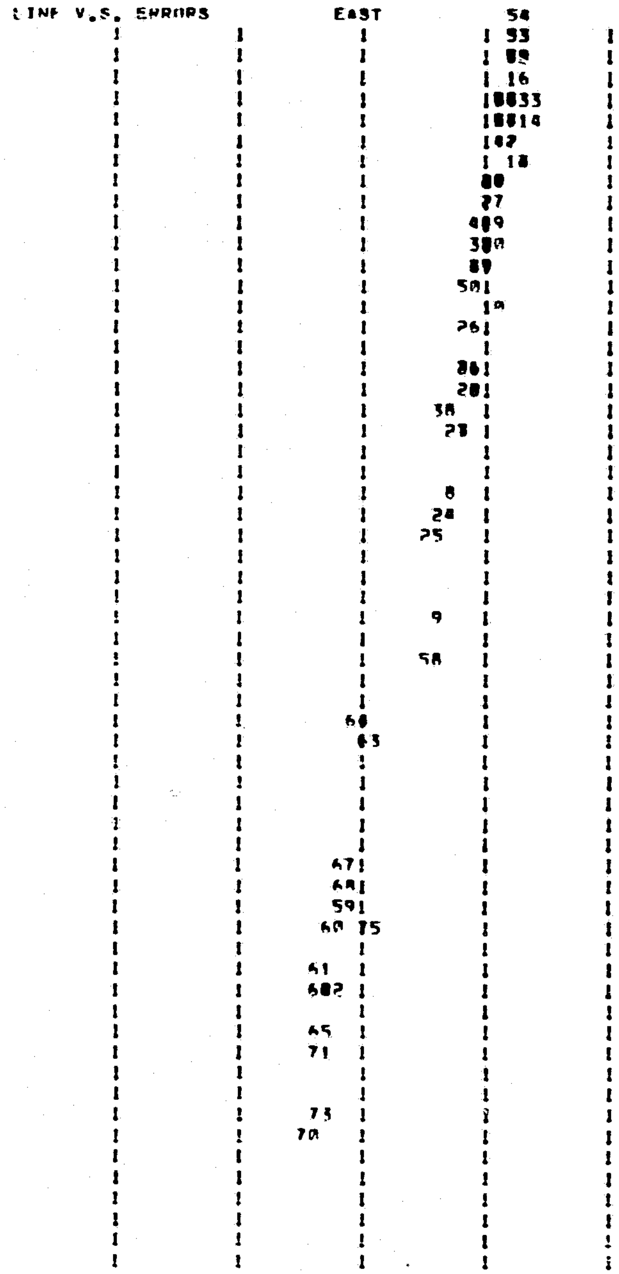

FIGURE 8. EAST-WEST ERRORS VERSUS NORTH-SOUTH POSITION AFTER HOM ROTATION

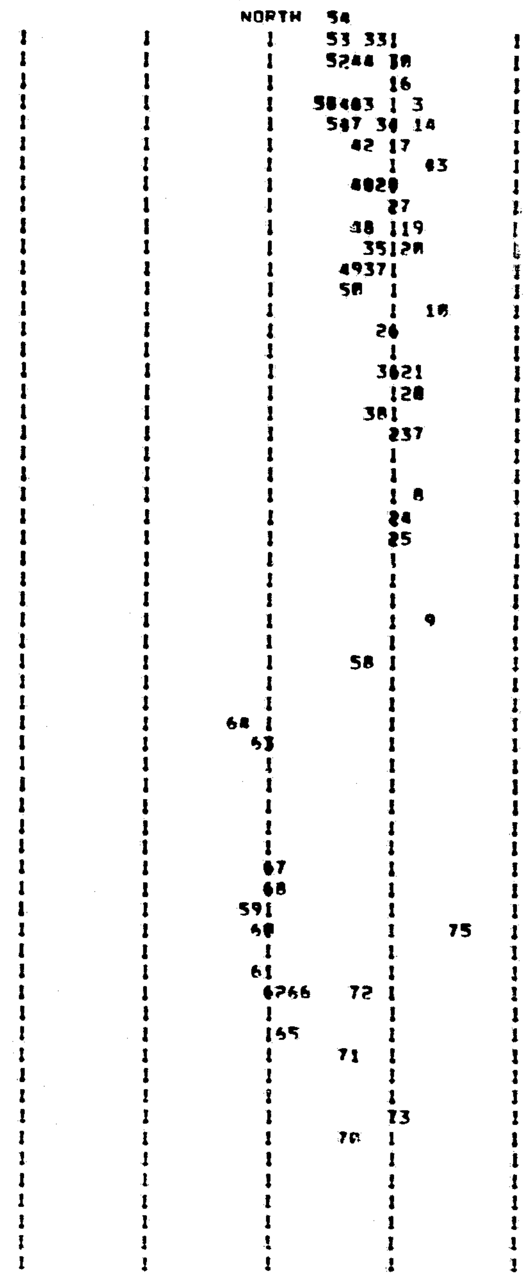

FIGURE 9. NORTH-SOUTH ERRORS VERSUS NORTH-SOUTH POSITION AFTER HOM ROTATION

estimate parameters that related the GSFC corrected data (intended to be HOM projection) to the true HOM projection and reduced residual errors to a minimum. Pitch, roll, yaw values and rates of change for pitch and roll are computed which allows correction to the same degree of accuracy as achieved with raw Landsat data, i.e., 50-125 meters rms.

Figures 10, 11, 12, and 13 show the residual errors for the scene considered above, scene ID 30500-15352. The plotting intervals in this case are 200 meters. The points are now clustered about the center line of each plot and only random deviations appear where systematic patterns of errors were formerly noted. The rms errors were 49.3 meters east-west and 43.1 meters north-south. The yaw term needed to correct the scene amounted to 22 milliradians or approximately 1.27 degrees, which, as noted above, is a large deviation from the documented HOM projection axis. A summary of geometric correction accuracy of GSFC and ERIM algorithms is shown in Table 2.

TABLE 2

GSFC AND ERIM GEOMETRIC CORRECTION ACCURACIES - P-FORMAT

	E-W Residual Errors (meters)	N-S Residual Errors (meters)
GSFC HOM Projection	4091.1	3306.4
GSFC Modified HOM	1834.7	1765.2
ERIM Model of HOM	49.3	43.1

Although the data has reduced radiometric fidelity due to cubic convolution resampling to produce the P-tape, ERIM geometric correction techniques are fully capable of correcting P-format data with geometric accuracy equaling ERIM X-format processing.

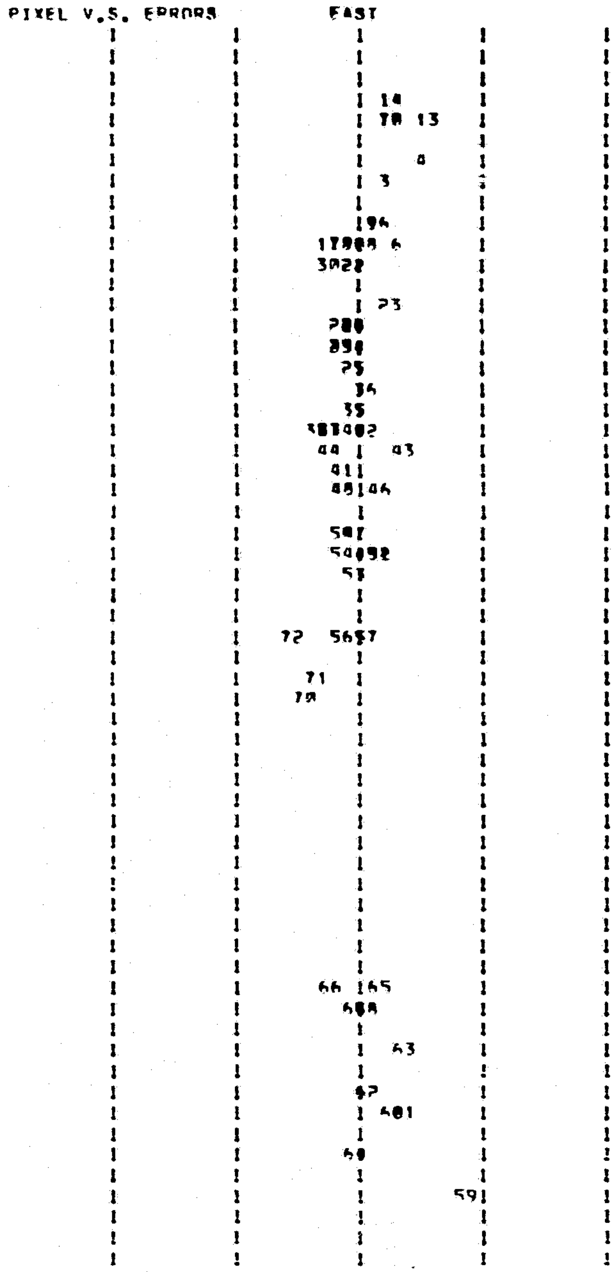

FIGURE 10. BEST FIT EAST-WEST ERRORS VERSUS EAST-WEST POSITION

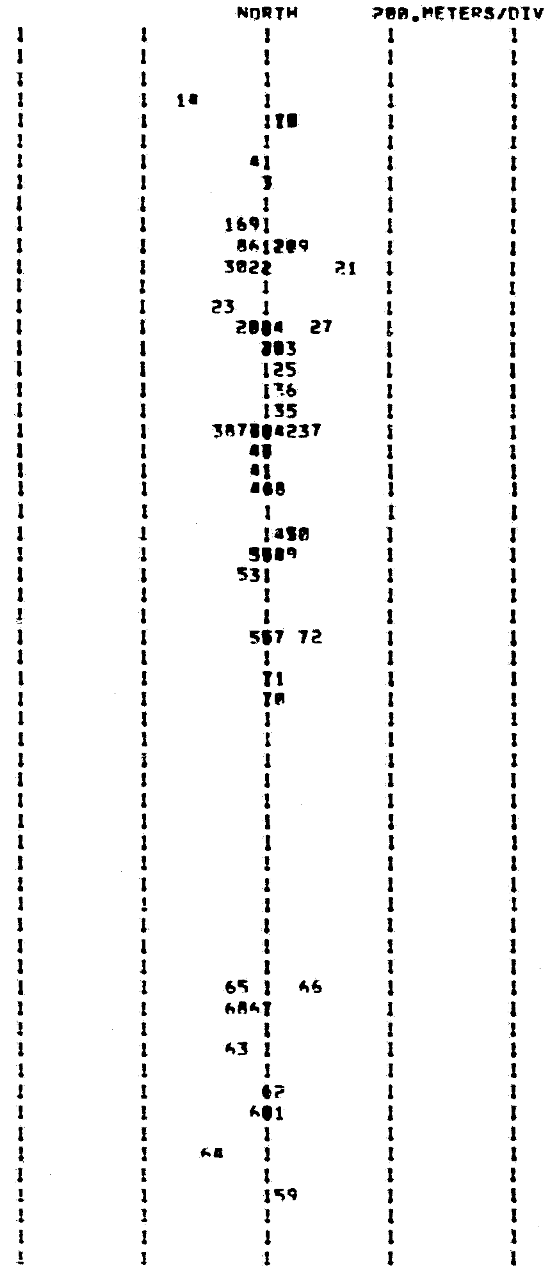

FIGURE 11. BEST FIT NORTH-SOUTH ERRORS VERSUS EAST-WEST POSITION

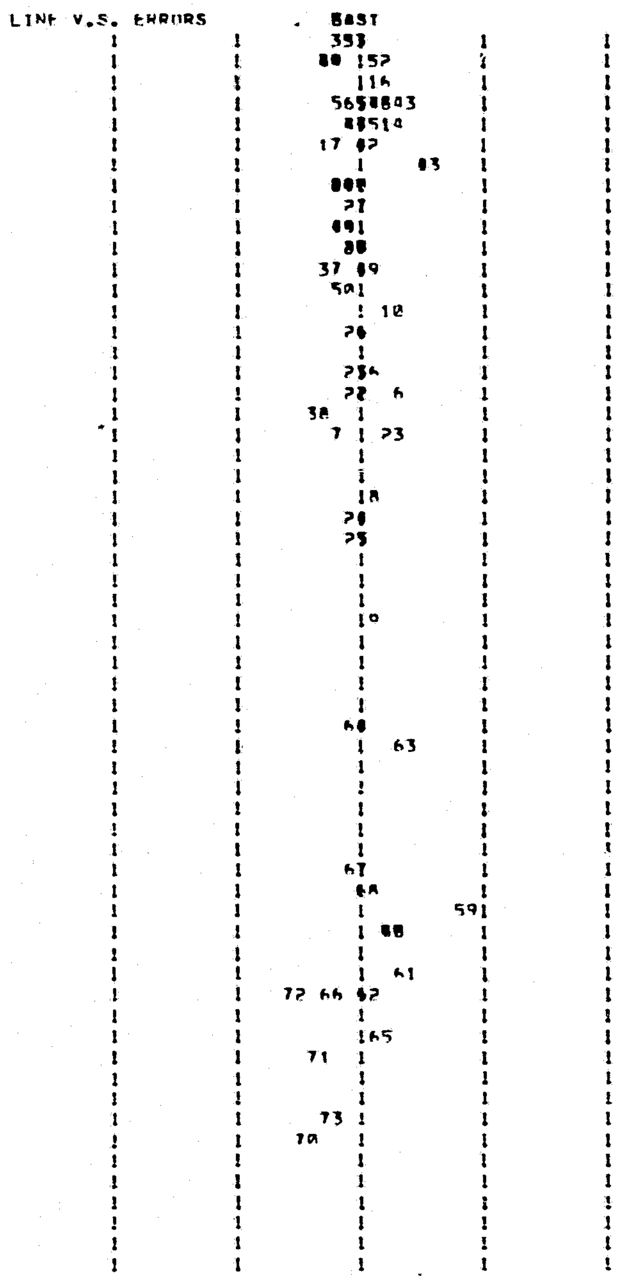

FIGURE 12. BEST FIT EAST-WEST ERRORS VERSUS NORTH-SOUTH POSITION

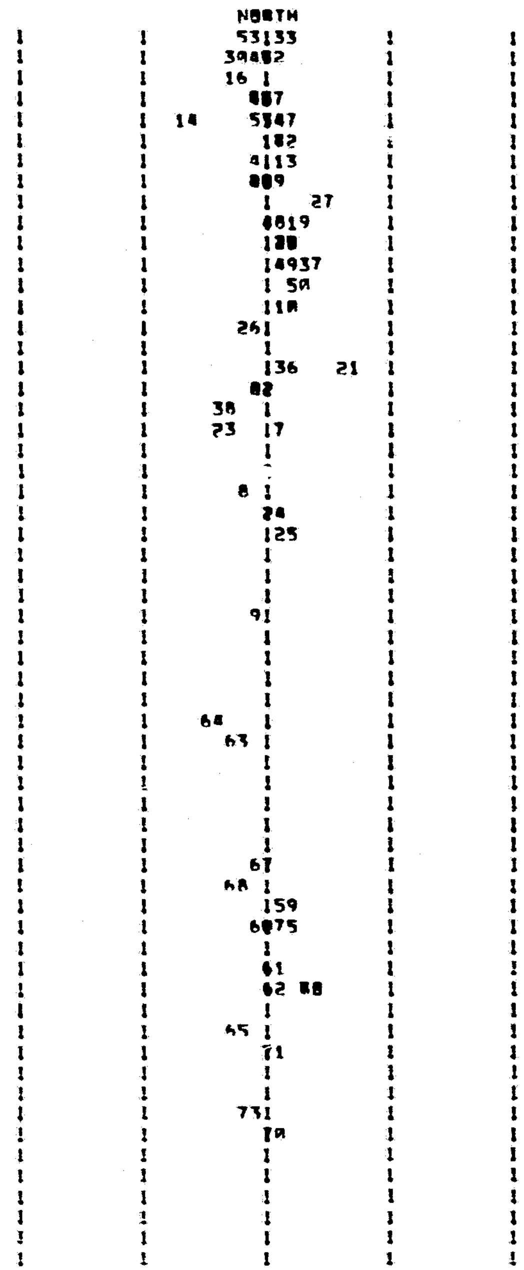

FIGURE 13. BEST FIT NORTH-SOUTH ERRORS VERSUS NORTH-SOUTH POSITION

2.3.2 X-FORMAT DATA

ERIM geometric correction techniques have been evaluated numerous times in recent years (Thomson, et al., 1980). The latest improvements in the ERIM Landsat model which incorporate roll and pitch acceleration adjustments have delivered the most accurate results. Previous studies have described ERIM's geometric correction processing in detail (Wilson, 1980). Figure 14 is a summary of ERIM capability. The first line reports results achieved for three different scenes in a test area in northern Ohio and southern Michigan using 90 conventional map-ground control point pairs. These values fall into the typical range of 50-125 meters rms for total residual errors. The remaining three lines depict the results obtained using satellite doppler survey equipment to locate ground control points which were used in place of map control points. In general, the errors decrease as the number of ground control points increase. Using 13 points achieves accuracy in the same 50-125 meter range as with conventional ground control points.

2.3.3 A-FORMAT DATA

In the future, data will be available without geometric correction processing on a tape known as the A-format data tape. While the format of the data will be quite similar to the P-format geometrically corrected data, the data conten will be more nearly like the data provided on X-format tapes. The A-format data will be radiometrically corrected but not geometrically corrected. Unlike the X-format tape, there is no emphemeris data provided.

ERIM expects to process A-format data in a manner virtually identical to the process used to correct X-format Landsat data. Since the data will not be cubically convolved, a substantial improvement in image quality should be produced when compared to P-format data. Because of the similarity to X-format data, there is every reason to believe that the A-format data can be corrected to the 50-125 meter range typical of X-format data if ephemeris data can be made available.

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	Scene 2189-15352 700M Roll, 400M Pitch (P-P acceleration)			Scene 5021-15271			Scene 11111-1522		
	E-W	N-S	Total	E-W	N-S	Total	E-W	N-S	Total
Errors Using Test Grid	66.9	43.2M	79.6M	41.9M	36.0M	55.2M	30.5M	36.6M	47.6M
Errors Using Three Points	233.6	72.0	244.4	60.1	75.1	96.2	74.6	41.7	85.5
Errors Using Five Points	103.1	63.8	121.2	50.0	44.6	67.8	43.2	63.0	76.4
Errors Using Thirteen Points	106.7	63.9	124.4	49.5	37.4	62.0	42.3	53.2	68.0

FIGURE 14. RESIDUAL ERRORS FOR SEVERAL LANDSAT SCENES MODEL MODIFIED TO INCLUDE SATELLITE ACCELERATIONS

2.4 CONCLUSIONS AND RECOMMENDATIONS

The GSFC system for Landsat data geometric correction using the Master Data Processor (MDP) is routinely producing "corrected" data sets. However, the lack of system documentation, apparent inconsistencies between the data and the available documentation, and the fact that the data are resampled into a projection different from any of the commonly used map projections make routine use of Landsat data from that system difficult at best.

The Forest Service has procured software from ERIM which is capable of correcting Landsat data to ground coordinates with apparently acceptable accuracy. A full test of this software should be done. To support this software the Forest Service will need a computer, image display hardware, and personnel time to select ground and image control points.

For the short term (AgRISTARS Program) we recommend that the Forest Service use ERIM to prepare Landsat data sets for analysis. An operational decision to get into the geometric correction business will involve factors such as personnel, computer systems, and better estimates of the operational data requirements of the Forest Service. Examination of such factors is beyond the scope of the current study.

In the meantime, the Forest Service should clearly enunciate its requirements for geometrically corrected data to NASA and other Federal agencies which might be in the Landsat data dissemination loop. This action might have beneficial results in that Forest Service requirements could be considered in future ground preprocessing system designs.

3
CHANGE DETECTION

One of the principal tasks of this project is to support activities designed to improve and demonstrate change detection procedures. Initial change detection procedures were demonstrated on an Idaho data set (Malila, 1980), and further development was demonstrated on a South Carolina data set (Colwell and Weber, 1981). The activities undertaken during the present project included improving operational procedures and demonstrating those procedures on a new data set (San Juan National Forest, Colorado). The following material describes the activities which occurred during this reporting period.

3.1 OPERATIONAL PROCEDURES

As a part of an attempt to improve operational procedures we investigated a variety of BLOB logics, as well as routine parameter setting for both BLOB and change vector analysis (CVA).

3.1.1 BLOB LOGIC

BLOB is an unsupervised clustering algorithm which was developed at ERIM for use in agricultural inventories (Kauth, et al, 1977). In addition to utilizing spectral information for clustering, BLOB also considers a pixel's spatial coordinates in the decision process. The benefits of BLOB include: (1) creation of spectrally homogeneous and spatially contiguous clusters; (2) data compression of from 10 to 30 depending on the application; and (3) a reduction in the noise of an image for subsequent processing.

Three BLOB decision logics were initially investigated using data for two dates from Kershaw County, South Carolina, to determine if any of the approaches is optimal in blob formation. The Kershaw data set was chosen for its mix of agricultural and forest lands, availability of medium scale photography, and familiarity with the area.

The first decision logic combines spectral information from the two dates and spatial information into one distance measure.

$$d_i^2 = \sum_{n=1}^{4} \frac{(x_{ni} - \bar{x}_n)^2}{VAR_n} + \frac{(L_i - \bar{L})^2}{VARL} + \frac{(P_i - \bar{P})^2}{VARP} \qquad \text{SPECTRAL/SPATIAL}$$

where x_{ni} are the signal values in band n

$\bar{x}_n$ is the mean vector for an active blob

L_i, P_i are line and pixel values for pixel i

$\bar{L}$, $\bar{P}$ are line and pixel mean values for an active blob

VARn, VARL, VARP are operator entered weights

n = channel of radiometric data

If the distance measure d_i^2 is greater than an operator specified threshold Tau, the decision is made that the pixel does not belong to that blob. The pixel is tested against all active blobs, and if it belongs to none of them, a new blob is established. If the pixel is assigned to an existing blob, the spectral and spatial means are updated. A blob becomes inactive when no pixels have been added to the blob during the last two scan lines.

The second decision logic is a separate spectral and spatial distance test, in which two distance measures are calculated:

$$d_1^2 = \sum_{n=1}^{4} \frac{(x_{ni} - \bar{x}_n)^2}{VARn} \qquad \text{SPECTRAL}$$

$$d_2^2 = \frac{(L_i - \bar{L})^2}{VARL} + \frac{(P_i - \bar{P})^2}{VARP} \qquad \text{SPATIAL}$$

Each distance measure is compared with a threshold, TAU1 or TAU2. If either d_1^2 or d_2^2 is larger than the respective thresholds for all active blobs, then a new blob is formed. If the pixel is assigned to an existing blob, the spectral and spatial means are updated.

The third logic is a separate date decision logic in which a combined spectral/spatial measure is determined separately for each date:

$$d_1^2 = \frac{(x_{1i} - \bar{x}_1)^2}{VAR(1)} + \frac{(x_{2i} - \bar{x}_2)^2}{VAR(2)} + \frac{(L_i - \bar{L})^2}{VARL} + \frac{(P_i - \bar{P})^2}{VARP} \qquad \text{DATE 1}$$

$$d_2^2 = \frac{(x_{3i} - \bar{x}_3)^2}{VAR(3)} + \frac{(x_{4i} - \bar{x}_4)^2}{VAR(4)} + \frac{(L_i - \bar{L})^2}{VARL} + \frac{(P_i - \bar{P})^2}{VARP} \qquad \text{DATE 2}$$

The two distance measures are compared to two thresholds, TAU1 and TAU2. If either of the pixel distances exceeds the threshold, the pixel begins a new blob. If the distance is less than the threshold, the pixel is assigned to the blob for which d_1 and d_2 are minimum, and the means are updated.

Numerous tests of the above BLOB logic options were made with different values for the operator supplied weights and thresholds. For example, the four spectral variances (VARn) were increased by 10% while holding Tau, VARL, and VARP constant. A module 16 system was used to color code the resulting blobs (every 16th blob would be the same color). A 35 mm color transparency was taken of each test using a Matrix camera and compared to cover type boundary maps of the small test areas within Kershaw County. MUPPET, a program which prints out the blob number associated with each pixel, was used to delineate blob boundaries in those instances where adjacent blobs were assigned the same color.

The tests led to the following conclusions. BLOB options #2 (separate spectral/spatial) and #3 (separate date) do not offer a clear advantage over option #1 (combined spectral/spatial) which was used in 1980 in South Carolina. We feel that all three options could produce essentially the same result if equivalent parameter settings were found, which would be a very time consuming process and was not attempted in these tests.

Blob formation appears much more sensitive to the spectral parameter settings than the spatial or Tau settings. A measure of sensitivity is the number of blobs formed in the study area. Table 3 shows the change in number of blobs and percent change for various parameter settings. The fact that the spatial parameter change is so small might also be caused by a default setting (VARL, VARP = 169) which is quite large, thus producing a very small relative change in the number of blobs and a potentially misleading measure of sensitivity.

TABLE 3

NUMBER OF BLOBS FORMED WITH VARIOUS PARAMETER SETTINGS

RIVER STUDY AREA

SETTING	NO. BLOBS	% CHANGE
Default	4176	
Spectral + 20%	3184	24%
Spectral + 50%	2572	19%
Default	4176	
Spatial + 20%	4165	.3%
Spatial + 50%	4158	.2%
Default	4176	
Tau + 10%	3683	11.8%
Tau + 20%	3525	4.3%

Large values of VARL, VARP relative to the four spectral settings emphasize the spectral variables rather than the spatial, and may produce blobs that are not very cohesive geographically. This may explain some of the long, narrow blobs that were observed.

3.1.2 BLOB PARAMETER SETTINGS

A routine procedure for initial setting of blob spectral parameters was developed on the South Carolina data set. Spectral signatures of targets of most interest (hardwood forest, conifer forest, mixed forest) were obtained and transformed to Greenness and Brightness (Kauth and Thomas, 1976) for both dates (G_1, G_2, B_1, B_2). The variance for each type was determined, and the average of the variances in each channel was used as the weighting factor in the BLOB algorithm. This technique was tested on the 1975 Kershaw County data, and produced values of 29 for VAR_{B1} and VAR_{B2}, and 18 for VAR_{G1} and VAR_{G2}. Examination of the blob image on a color display and with MUPPET showed no problems with feature boundaries being crossed by individual blobs. Whether this method produces "optimal" parameter settings is a subjective judgement for the user. We feel it is more acceptable to have a large field subdivided into several blobs by smaller spectral parameter settings, than for larger settings to produce one large blob which may cross the feature boundary. As a minimum, this technique should provide the user with an acceptable "ballpark" figure from which to proceed with further manipulations of the parameter values, if so desired.

Routine procedures for setting Tau, VARL, and VARP will be more subjective. Spatial parameters must reflect the spatial variability within the scene. Large homogeneous forested tracts may best be served by a relatively large spatial setting as was employed in South Carolina (VARL, VARP = 169). Areas with a substantial mixing of forest species or forest/non-forest types would require a smaller VARL, VARP in order to put more weight on that term of the BLOB decision logic. As an example, let us again examine the BLOB decision logic,

$$d_i^2 = \sum_{n=1}^{4} \frac{(x_{ni} - \bar{x})^2}{VAR_n} + \frac{(L_i - \bar{L})^2}{VARL} + \frac{(P_i - \bar{P})^2}{VARP}$$

If Tau = 35, and VARL, VARP = 169, then a pixel which is 13 lines and 13 pixels away from an active blob mean produces the fractions $(13)^2/169 + (13)^2/169$ for the spatial portion of the above equation. The spatial "contribution" to the decision if that pixel should be added to that blob, is

$$\frac{\frac{(13)^2}{169} + \frac{(13)^2}{169}}{Tau} = \frac{2}{35} = 6\%.$$

If one felt that the spatial relationshipi should play a more important role in the decision, a decrease in VARL and VARP to 81 would give a 12% weight to that same pixel. Blob spatial parameter settings for AgRISTARS have been in the range of 4 to 18, as that work includes areas with small agricultural fields.

The value of Tau was set at 35 for previous work in Kershaw County. This setting was developed by successive iterations until several small (5-10 ac) test fields were each being clustered into one blob. Increases in the value of Tau will produce larger blobs, but the risk of the blobs crossing type boundaries increases. Again, the final setting for Tau will involve mostly user judgement as to what is "optimal" and will depend on the degree of heterogeneity in the scene.

3.1.3. CVA LOGIC

CVA logic is dependent on the magnitude and angle of change in Greenness and Brightness for blobs formed from analysis of two-date data (see Figures 15a, b). Our previous work (e.g., Colwell and Weber, 1981) has shown that the significance of a change vector magnitude and angle may depend on the feature on which the change occurred. We are currently not using all the available information in assessing whether a change

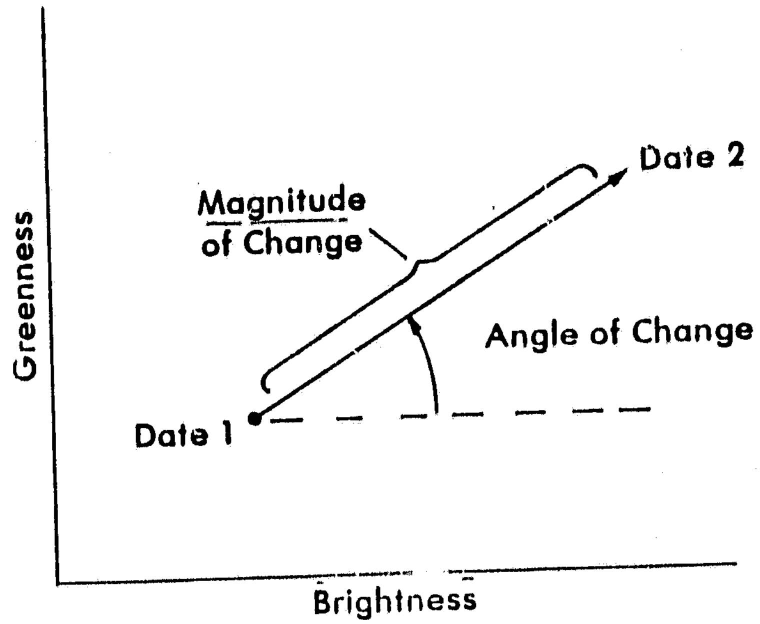

FIGURE 15a. ILLUSTRATION OF SPECTRAL CHANGE VECTOR

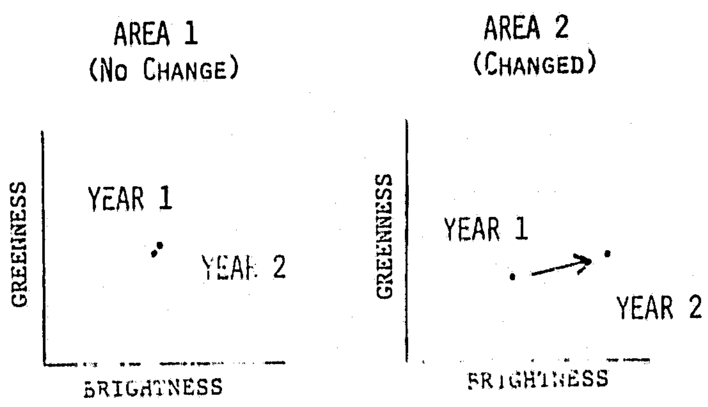

FIGURE 15b. PRINCIPLE OF CHANGE VECTOR ANALYSIS

has occurred and/or the kind of change it is. The following figure (Figure 15c) illustrates the situation.

As far as current CVA logic is concerned, spectral change for feature A from date 1 to date 2 has exactly the same significance as change for feature B. In reality, one of these may represent a fundamental change of interest, whereas the other may be of no interest. Alternatively, they may both be real changes, but different kinds of changes.

Our realization of this situation was in part responsible for our stratification of data into forest and non-forest categories on the previous project in South Carolina. It may be that additional spectral stratification (e.g., classification on the basis of BLOB mean values) may be necessary in the future. It is our expectation that CVA logic software will make this option possible, either by traditional classification logic or expansion of the look-up table.

There are other ways of preserving some information about the nature of a feature for assessing the significance of spectral change. One such way is to compute the magnitude of change relative to the date 1 value of G_1 and B_1 (proportional change). Such a proportional change measure would differentiate between change in features A and B diagrammed previously.

We intend to investigate the above considerations in the course of this project. Funding considerations will determine how much of this can be done and how soon. In the interim, we will continue to use the standard CVA procedure, which has worked reasonably well in the past.

3.1.4 CVA PARAMETER SETTING

A great many factors can affect appropriate levels of CVA parameters. Procedures for setting optimal parameters may vary with the amount of information available.

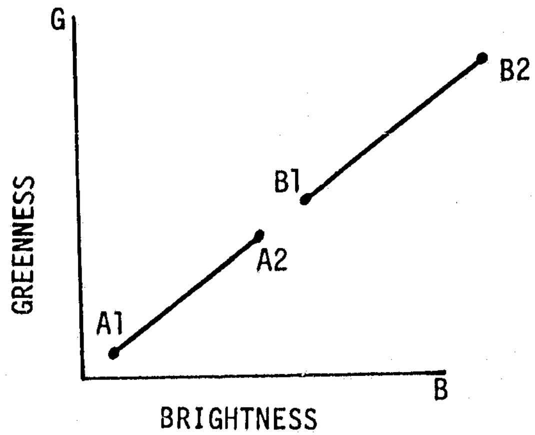

FIGURE 15c. ILLUSTRATION OF NEED FOR SPECTRAL STRATIFICATION IN CHANGE DETECTION

If information on the spectral nature of selected changes is available, it can be used directly. Alternatively, optimal magnitude and angle values can be assessed on a trial and error basis, by examining "trial" change images with several different parameter settings and assessing which "seems" best, based on whatever information concerning change is available.

Optimal parameter setting procedures have not yet been established. The intention is to further study this issue at a later date.

3.1.5 RADIOMETRIC NORMALIZATION

The issue of scene-to-scene (date 1-to-date 2) radiometric normalization will also have to be addressed, and a "routine procedure" will have to be adopted. This may prove to be a considerable task, as the following discussion suggests.

Empirical data normalization by "matching scenes" will be complicated by the fact that some target features have physically changed whereas other target features may appear different because of phenological differences. In areas of considerable topography certain slopes and aspects may have higher irradiance on day 2 than on day 1, whereas other slopes and aspects may have lower irradiance. On some scenes (e.g., South Carolina) analysis of a TASCAP Yellowness haze diagnostic will not be possible because of one or more unusable Landsat bands on one or both dates.

In addition, the fact that terrain features have non-Lambertian <u>bidirectional</u> reflectance suggests that there is <u>no single</u> correction factor that is applicable to the whole scene (see Colwell, 1981). The change in bidirectional <u>reflectance</u> of a dense forest may actually be different from that of a sparse forest between two dates if the solar elevation angles are significantly different (as they were for South Carolina). This difference in reflectance could be largely attributable to different relative amount of shadow in the two canopies on the two dates. And any change in reflectance of either canopy will probably require a different normalization than relatively Lambertian constant-reflecting features such as most soils. It seems entirely possible that additional bidirectional reflectance effects will be seen in forest canopies on different slopes and aspects. These hypothesized effects would be in addition to those effects of different irradiance.

A TASCAP Yellowness haze diagnostic might seem to be useful (if it could be computed) as a measure of differential atmospheric effects, to which it nominally is sensitive. However, in scenes that contain any features with "Yellowish" characteristics which change from scene-to-scene (e.g., senescent grassland, diseased or dead trees, "turning" aspen and oak) the Yellowness diagnostic would presumably not be an unambiguous measure of only atmospheric conditions.

In addition to all of the above factors, the calibration of the Landsat data from two different dates may be different. Attempts to use EDIPS and non-EDIPS data have certainly demonstrated this fact (see Section 3.2.1).

In summary, there are many theoretical reasons why two data sets may not be radiometrically equivalent. Our present understanding of these factors does not always furnish a theoretical basis for correctly normalizing the data. Until this understanding improves, we suggest that the routine procedure be empirical, and that it be based on "matching" a variety of apparently unchanged features (both vegetated and unvegetated) in the two scenes.

3.1.6 STRATIFICATION

Previous experience has shown us the desirability of stratifying the scene into forest and non-forest categories. We expect this to be the general situation. The present procedure for such stratification has been a simple Greenness-Brightness look-up table. We expect to investigate more sophisticated procedures and the desirability of additional strata in future activities.

We know that change detection is going to be complicated in some scenes by clouds, cloud shadows, and snow occurring on one date but not the other. Such features do not represent fundamental changes which we wish to draw attention to. In addition, such changes may have vector magnitudes and angles that preclude them being separated from other changes of interest.

Accordingly, we believe that there is a need to "stratify-out" such data prior to change detection. Perhaps the SCREEN algorithm will serve this purpose, but it is not currently a part of operational procedures.

3.2 COLORADO CHANGE DETECTION

Subsequent to investigation of operational procedures, we have begun to investigate changes in part of the San Juan National Forest in southwest Colorado, using the Rampart Hills 7.5' quadrangle as a test site. These activities are described in the following material.

3.2.1 DATA BASE SELECTION AND PREPARATION

Landsat scenes from 13 July 1978 (E21268-16533-4) and 20 July 1980 (82200617133X0) were selected for this task in order to correspond as closely as possible in date to available 1:30,000 large format color IR transparencies of the study area, and to be as close to each other as possible in overpass time. Although the photo coverage was flown on 28 August 1978 and 29 September 1980, Landsat coverage earlier in the summer was chosen to eliminate false change indication due solely to the fall color change. Both scenes are virtually snow-free within the study area, but the July 1980 scene has a small amount of cloud shadow present. A portion of the 1980 scene showing most of the Rampart Hills quadrangle is shown in Figure 16. This figure and subsequent Rampart Hills images are at an approximate scale of 1" = 1 mile. All subsequent

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Figure 16. 1980 False color image of Rampart Hills quadrangle study area.

figures are Matrix camera prints (rather than Optronix filmed images), in order to reduce costs.

Different data preparation techniques were utilized for the two scenes. The 1978 scene was raw data from EROS while the 1980 scene was in the EDIPS geometrically corrected format. The EDIPS 57 m grid Hotine projection was resampled to a 50 m UTM grid using the nearest neighbor technique. The EROS raw data was resampled to a 50 m UTM grid using ERIM's restoration procedure. Both sets of data were then geometrically corrected using the same set of ground control points - the EROS data by a non-linear model developed at ERIM, and the EDIPS data with non-linear regression analysis.

Before implementing the BLOB/CVA procedure on the Colorado data set, the data must first be transformed from eight channels of Landsat (two dates) to four channels of Brightness and Greenness. One approach is to apply the coefficients and offsets developed by Kauth & Thomas (1976). This method was not used, as those coefficients were developed from an agricultural scene in Illinois and may not be representative of the range of conditions found in the mountainous, forested environment of the San Juan National Forest. Also, the EDIPS coefficients necessary to utilize the Tasseled Cap procedure were not available.

The following approach was used to develop a set of coefficients to transform the Colorado data. Four-band spectral signatures for the cover types present were extracted for each date. The cover types included bare soils (a range of dark to light toned), improved range, aspen, oak brush, upland conifer (mostly spruce and fir), lowland conifer (mostly ponderosa pine), open or cutover areas, and bare rock. Many signatures were taken in the bare soil category to ensure that the first principal component of variation would be parallel to the bare soil line. Subsequent analysis proved this had been achieved.

The coefficients of the first two principal components of variation (PC1, PC2) were computed from the spectral signatures and applied to the

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test site data. These two components, Brightness and Greenness, represent over 99% of the variation in the data set. Since the respective coefficients for the two dates were almost identical, they were averaged so that a single set of coefficients could be utilized for both dates. These average coefficients are shown in Table 4.

TABLE 4

COEFFICIENTS USED TO TRANSFORM LANDSAT DATA

	PC1 (Brightness)	PC2 (Greenness)
MSS4	.198	-.380
MSS5	.425	-.754
MSS6	.630	.113
MSS7	.619	.524

In order to radiometrically normalize the two dates of data, radiometric corrections were empirically established using the procedure described in Section 3.1.5.

The 1978 Landsat tape was received in raw data format, while the 1980 tape had been EDIPS processed, creating a large discrepancy in the radiometric calibration for the two tapes. A correction factor for the 1980 tape was calculated from the ratio of the average spectral values of the previously derived signatures for each band for the two dates. These corrections empirically include a correction for different irradiance for different sun angle. The following adjustments were indicated:

MSS4 (1980) x 1.813; i.e., MSS4(1978)/MSS4(1980) = 1.813

MSS5 (1980) x 1.852

MSS6 (1980) x 1.790

MSS7 (1980) x 1.744

In order to utilize the full range of data values available in ERDC, and to equalize the Brightness/Greenness scales for the future

CVA, a scale factor was applied to the Greenness measure. An offset of 64 was added to the Greenness values in order to avoid negative numbers.

The Brightness and Greenness coefficients implemented for this data set based on all of the above considerations are shown in Table 5.

TABLE 5
BRIGHTNESS AND GREENNESS TRANSFORMATION

Brightness 1 (1978) = .198 MSS4 + .425 MSS5 + .630 MSS6 + .619 MSS7
Greenness 1 (1978) = -.761 MSS4 - 1.507 MSS5 + .227 MSS6 + 1.048 MSS7 + 64
Brightness 2 (1980) = .359 MSS4 + .787 MSS5 + 1.128 MSS6 + 1.080 MSS7
Greenness 2 (1980) = -1.378 MSS4 - 2.791 MSS5 + .406 MSS6 + 1.827 MSS7 + 64

3.2.2 CHANGE CLASSIFICATION SYSTEM

Change classification strategies were discussed with San Juan National Forest personnel at a meeting in Durango, Colorado in May of 1981. At that time it was decided that the information that was required was <u>where</u> and <u>when</u> to change the data base, but not <u>how</u> to change the data base. Therefore, it was decided that the particular change classification that was used was not critical. For lack of any compelling reason to change the system used previously in South Carolina, we decided to use that system again. The change classification system we used is indicated in Figure 17. It is similar to the classification system used by Damien Lepoutre of the NFAP, which facilitates comparison of results.

3.2.3 CHANGE IMAGE ANALYSIS

The geometrically corrected and merged Landsat data from 1978 and 1980 were used to construct a two-date change image. Such an image had been found useful in previous investigations (e.g., Colwell and Weber, 1981) for making subjective estimates of amount and kind of change.

CHANGE

I. Forest Change
   A. Loss of Vegetation
      1. complete
         a. hardwood
         b. conifer
         c. hardwood/conifer mixture
      2. partial
   B. Gain of Vegetation
      1. complete
         a. hardwood
         b. conifer
         c. hardwood/conifer mixture
      2. partial
   C. Undetermined change not associated with gain or loss of vegetation (e.g., phenology?)

II. Non-Forest Change
   A. Loss of Vegetation
      1. complete
         a.....?t.b.d.
      2. partial
   B. Gain of Vegetation
      1. complete
         a. ...?t.b.d.
      2. partial
   C. Undetermined change not associated with vegetation (e.g., bare → water)

NO CHANGE

Ignore in any further analysis -- not of interest

FIGURE 17. CHANGE DETECTION CLASSIFICATION SYSTEM

A two-date change image was produced by color coding 1978 MSS5 as blue, 1978 MSS7 as red, and 1980 MSS7 as green. Copies of this change image at a scale of 1/2" = 1 mile were left with San Juan National Forest personnel for their use and/or analysis. Another change image at a scale of 1" = 1 mile was produced based on Brightness and Greenness , and it is shown in Figure 18. This image was produced by color coding 1980 Brightness as blue, 1978 Greenness as red and 1980 Greenness as green. A gain of vegetation from 1978 to 1980 is indicated by red to magenta colors, whereas loss of vegetation is indicated by cyan colors.

We have examined these change images in order to assess their usefulness and information content. We based our cursory analysis on limited on-site investigation, plus analysis of large format color infrared aerial photography and results of photo-interpreted change detection performed by Damien Lepoutre. Some areas experiencing loss or gain of vegetation are easily located on the change image. On the other hand, some areas of subtle change or small areal extent are difficult to locate, and some areas in which no known change occurred have indications of change on the change image. Our initial conclusion is that correct and unambiguous detection of the limited amount of change which has occurred on this particular test site is very difficult based on two-date Landsat image analysis. Perhaps the digital techniques employed in BLOB/CVA will be helpful for locating small areas of subtle change, but even that is expected to be a difficult task.

3.2.4 DIGITAL CHANGE DETECTION

The geometrically corrected and merged Landsat data from 1978 and 1980 were subsequently used to assess change on the basis of digital change detection procedures (BLOB/CVA). Such procedures had been found to be useful in previous investigations (e.g., Colwell, et al., 1980; Malila, 1980).

The BLOB/CVA change detection procedure as we are implementing it is shown in Figure 19. Geometric correction and merging, as well as

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Figure 18. Two date change image.
1980 Brightness=blue, 1978 Greenness=red, 1980 Greenness=green

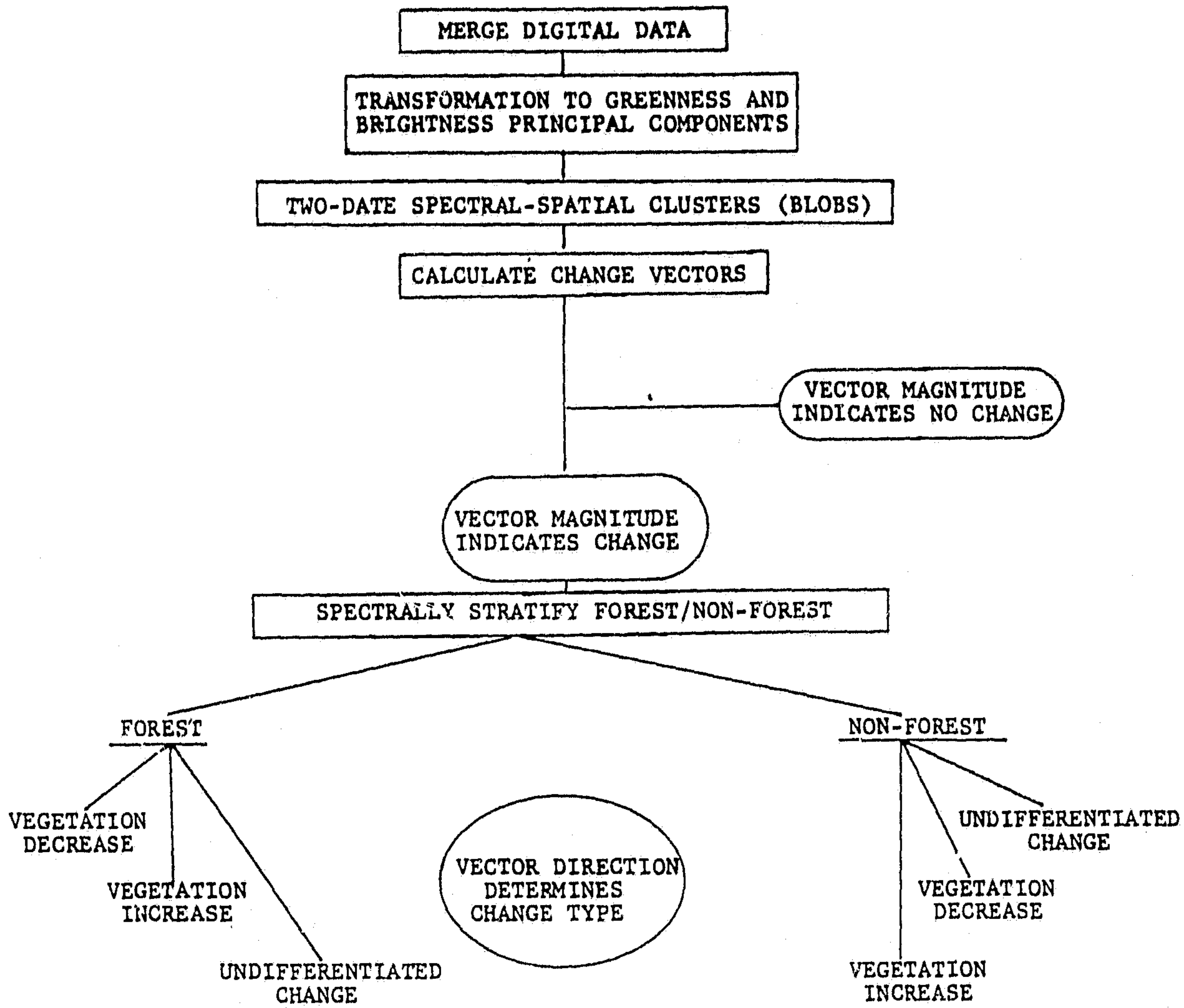

FIGURE 19. Strategy for BLOB/CVA Change Detection

radiometric calibration and Brightness/Greenness transformation have been described in earlier sections of this report. This section will describe activities involved in BLOB parameter setting and forest/non-forest stratification. Progress on the other aspects of the procedure will be presented in subsequent documents.

3.2.4.1 BLOB Parameter Setting

The procedure for estimating BLOB parameter settings which was outlined in section 3.1.2 was used on the Rampart Hills quad study area. Brightness and Greenness values were obtained for five training sets in each of three main forest types: conifers, hardwoods, and oak brush. The average value and variance in each channel, as well as the average variance for the three cover types is shown in Table 6. For the final BLOB spectral parameter settings, the Greenness values were divided by 2 to take into account their greater range of values and to put more weight on those channels in the BLOB algorithm.

$$G_1/2 = 39.5/2 \doteq 20$$
$$G_2/2 = 38/2 \doteq 20$$

The Brightness channels were set at 28.

TABLE 6

AVERAGE BRIGHTNESS AND GREENNESS VALUES FOR THREE FOREST TYPES

		B_1	G_1	B_2	G_2
Pine/Spruce	$\bar{x}$	42.7	85.9	45.8	83.5
	s^2	52.8	89.8	56.7	87.7
Aspen	$\bar{x}$	81.2	176.1	75.2	159.5
	s^2	13.5	8.6	8.5	8.0
Oak Brush	$\bar{x}$	72.6	121.9	70.9	111.4
	s^2	16.8	20.1	14.8	18.3
AVERAGE VARIANCE		27.7	39.5	26.6	38.0

In order to emphasize the spectral parameters for change detection, the values of VARL, VARP, and TAU were set at 144, 144, and 30, respectively. These settings produced 7932 blobs from a study area containing 65,036 pixels. This is less than the magnitude of data compression BLOB was designed for, but it was felt that since the areas of clearcuts in the study area were small, a large number of blobs with an average size of 8-10 pixels was necessary.

A BLOB image of a portion of the Rampart Hills study site is shown in Figure 20. Every 16th blob formed has the same color.

3.2.4.2 Stratification

Previous BLOB/CVA change detection activities had shown that the magnitudes and angles of certain kinds of forest changes could be similar to certain kinds of non-forest changes. In order to make these fundamentally different kinds of changes distinguishable from each other, we previously stratified the scene into forest and non-forest on the basis of a Brightness/Greenness look-up table (Colwell, et al, 1980). The same approach was used on the current Colorado data set.

A look-up table for the Colorado data was established for 1978 Brightness and Greenness values. The forest/non-forest boundary in the look-up table was established on the basis of the supervised signatures of various terrain types. The resulting look-up table was applied to 1978 blob mean values of Brightness and Greenness.

3.3 FUTURE PLANS

CVA parameters of magnitude and direction of forest and nonforest changes are being determined. Once these parameter settings have been established, BLOB/CVA change images will be prepared and evaluated.

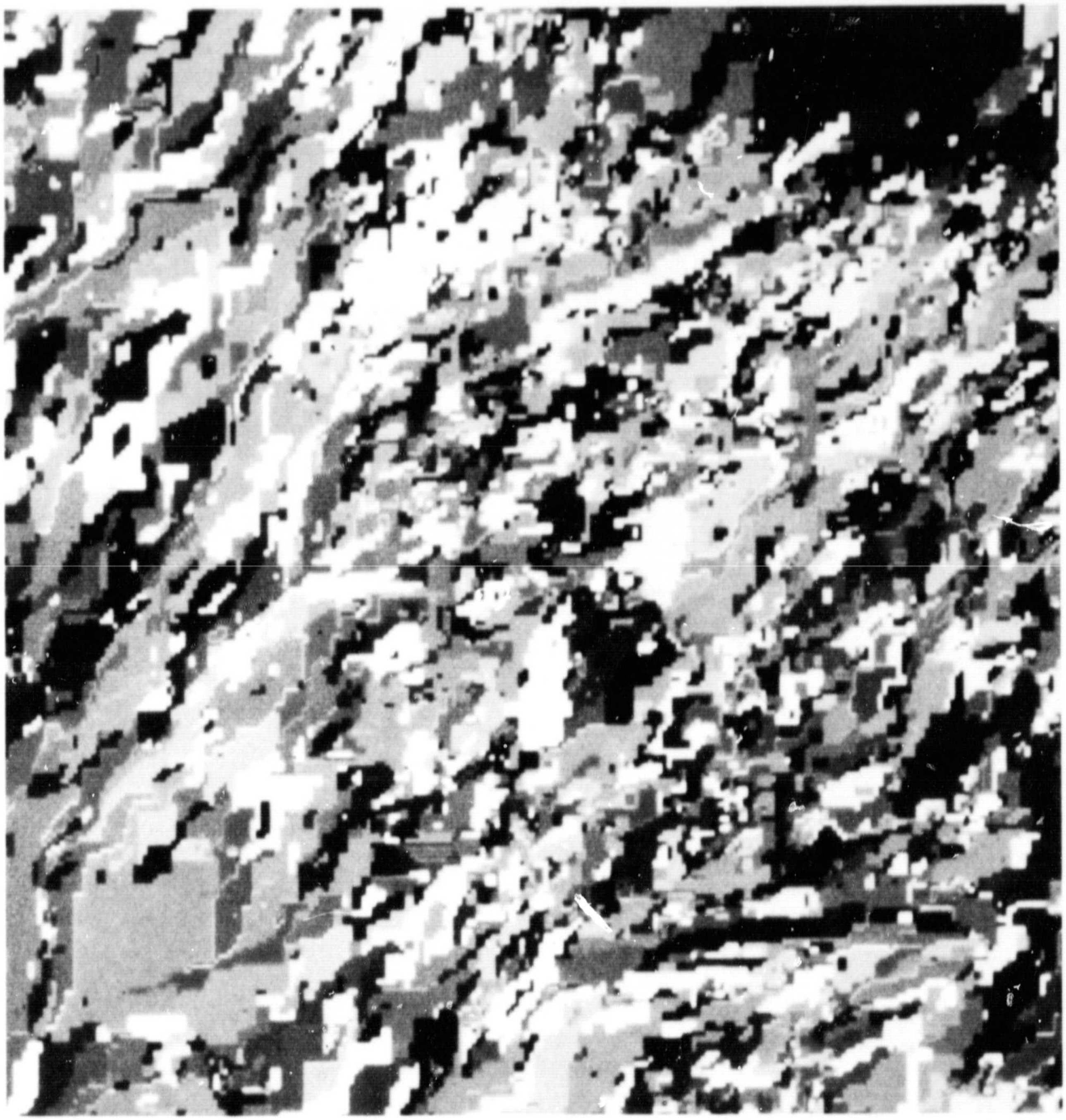

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Figure 20. BLOB image of Rampart Hills study area. Every 16th blob formed is assigned the same color.

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4
RESOURCE SUITABILITY

Another major task of this project has been to investigate and demonstrate procedures which may prove useful for assessment of the capability and suitability of units of terrain for various types of natural resource utilization. Site capability has historically been based on an analysis of fundamental features of the terrain, whereas suitability has included analysis of economic, political, social and technical factors. Although most of the procedures we address here are primaraily related to site capability, the line between capability and suitability becomes blurred when including such factors as present mechanical limitations as a function of slope, or assessing the effects of present active roads. Because of this ambiguity, we have chosen to refer to all of our activities reported here as a partial (incomplete) assessment of site suitability.

4.1 BACKGROUND

A trip was made to the San Juan National Forest in May of 1981. Discussions with San Juan National Forest personnel during that trip were helpful in understanding goals and priorities with respect to assessment of site suitability. Several important decisions were made. It was decided that initial ERIM efforts at helping to assess suitability should concentrate on (1) timber; (2) grazing; and (3) wildlife habitat. It was also decided that initial efforts should occur on the Rampart Hills 7-1/2' quadrangle.

4.2 DATA BASE ASSEMBLY

Site suitability is a function of many characteristics of a site and its environs. Therefore, assessment of site suitability is dependent on an adequate data base of relevant information. We decided that it was most cost and time effective for ERIM to produce some initial data base components for initial investigations of assessment of site suitability.

It is anticipated that subsequent ERIM assessments of site suitability over larger areas and with a more complete data base will utilize data base components (layers) developed by San Juan National Forest personnel and other NFAP investigators (e.g., Lockheed).

4.2.1 COMPONENTS OF DATA BASE

The fundamental data base components developed for the Rampart Hills quadrangle by ERIM were (1) land cover; (2) topography; and (3) road location. In addition, these basic components were used to derive additional components. These activities are described in the following sections.

4.2.1.1 Topography

Management of forest lands in regions of considerable relief is dependent on knowledge of local topography. Topography affects both the ecological conditions at a given site and also the management options which are reasonable and feasible. Accordingly, it was decided that one of the primary data layers should contain topographic information.

Digitized topographic information on computer tape was obtained from the National Cartographic Information Center of the U.S. Geological Survey. This information was geometrically corrected and resampled into 50 x 50 meter pixels in a projection equivalent to the Landsat data (see 3.4.2). The result was a file of elevation data. This file was subsequently linearly interpolated to produce a slope file.

4.2.1.2 Land Cover

The current data layer of land cover for the San Juan National Forest is based on Landsat classification, modified in some cases by the judgement of local field personnel. There is some question about the reliability of this data layer, which is currently being subjected to accuracy assessment. There is also a tendency for the classified Landsat data to have a salt and pepper appearance, which could make analysis of edge and juxtaposition somewhat suspect. A land cover data layer developed from interpretation of aerial photography is currently being developed (Ward, 1981), but is presently not available.

In view of the above situation, we decided that it might be helpful to investigate the relative usefulness of a categorized-blob land cover data layer. Although a classified blob image has never been produced before, theoretical considerations suggest it might be useful. Individual pixel "noise" would likely be reduced due to the spatial smoothing associated with blob formation. Furthermore, classification of spatially similar entities is in keeping with management on the basis of "stand" units. In addition, since blobs had to be formed for the change detection task, half of the blob classification procedure (i.e., "BLOBing") had already been planned (see Section 3.2.4.1). All that remained was to categorize these blobs.

Like many other new procedures, however, this additional step required more effort than initially expected. The procedure involved clustering the blobs based on their 1980 mean values of Greenness and Brightness. The resulting cluster mean values of Greenness and Brightness were then assigned to land cover classes (i.e., they were labeled) by analysis of their position in Greenness and Brightness space relative to the position of previously extracted supervised (training set) signatures. Because of very limited field information with respect to species composition, tree age and density, the classification categories were made quite general (Table 7).

TABLE 7

CLASSIFICATION CATEGORIES FOR CLUSTERED-BLOB DATA

(1) Lowland Conifer (principally Ponderosa Pine, also Pinyon/Juniper)

(2) Upland Conifer (principally Engleman Spruce, White Fir, Alpine Fir, and Douglas-Fir)

(3) Aspen

(4) Mixed Hardwood/Conifer (a mixture of 1 and 3 or 2 and 3)

(5) Oakbrush (mainly Gambel Oak)

(6) Open or Poorly Stocked (little or no forest overstory, with grass and/or brush understory, frequently a disturbed area, including logging)

(7) Meadow/Grass (no forest overstory; grasses and forbs predominate)

(8) Bare (little or no vegetation)

(9) Water

(10) Shadow

An image of the categorized (labeled) clusters is shown in Figure 21. Examination revealed that some of the clusters incorporated spectrally similar blobs formed on ecologically distinct categories. For example, some blobs representing sparse lowland conifer (principally Ponderosa Pine) were clustered with some blobs representing sparse upland conifer (largely Spruce-Fir). Assigning labels to individual blobs would have furnished a solution to this problem, but such a solution is considered unwieldy for a large number of blobs.

As a more tractable alternative to this approach we decided to use elevation data to modify the cluster label for associated blobs. The importance of elevation data to adequate Landsat categorization of the San Juan National Forest has been demonstrated previously (e.g., Hoffer, et al., 1979).

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Figure 21. Classified (labeled) BLOB Clusters of Rampart Hills.

UPLAND CONIFER	MEADOW
LOWLAND CONIFER	OPEN/POORLY STOCKED
ASPEN	BARE
MIXED FOREST	WATER
OAKBRUSH	CLOUD SHADOW

Using ecological data on elevation ranges of vegetation types (Hoffer, et al, 1979), as well as limited field information obtained in the on-site visit in May 1981, we established elevation thresholds for stratifying the clusters into upland and lowland types. The resulting elevation-stratified Blob (cluster) classification image is shown in Figure 22. This data was used as the land cover layer of our data base.

4.2.1.3 Roads

Roads affect both management options and resource potential. Therefore, the presence or absence of roads was included as another layer in the data base. This layer was prepared by digitizing the improved road network within Rampart Hills quadrangle from a 1962 USGS Quad map. This digitized data was then geometrically corrected and resampled to fit the other layers of the data base (see Figure 23). The same procedure could have been performed for unimproved roads, permanent and intermittent streams, and other features. The road file was subsequently converted to a file containing information on the distance of each cell from the nearest road (see Section 4.5.1.4 and Figure 24).

4.3 FOREST SUITABILITY

The suitability of land for production of forest products is affected by a variety of factors, including (1) type of vegetation; (2) slope of the land; and (3) distance to existing roads. During the ERIM visit to Durango there was an indication of Forest Service personnel interest in being able to produce data and/or maps representing the joint occurrence of various conditions. The Geographic Information System (GIS) capabilities being developed at ERIM enable this kind of product to be produced. As an example of this GIS capability all stands of a certain kind of timber (upland conifer) located on a certain slope class ($\leq$60%), and within a certain distance of a road (<1.5 km), were displayed (Figure 25).

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Figure 22. Elevation Stratified BLOB Classification for Rampart Hills.

UPLAND CONIFER	MEADOW
LOWLAND CONIFER	OPEN/POORLY STOCKED
ASPEN	BARE
MIXED FOREST	WATER
OAKBRUSH	CLOUD SHADOW

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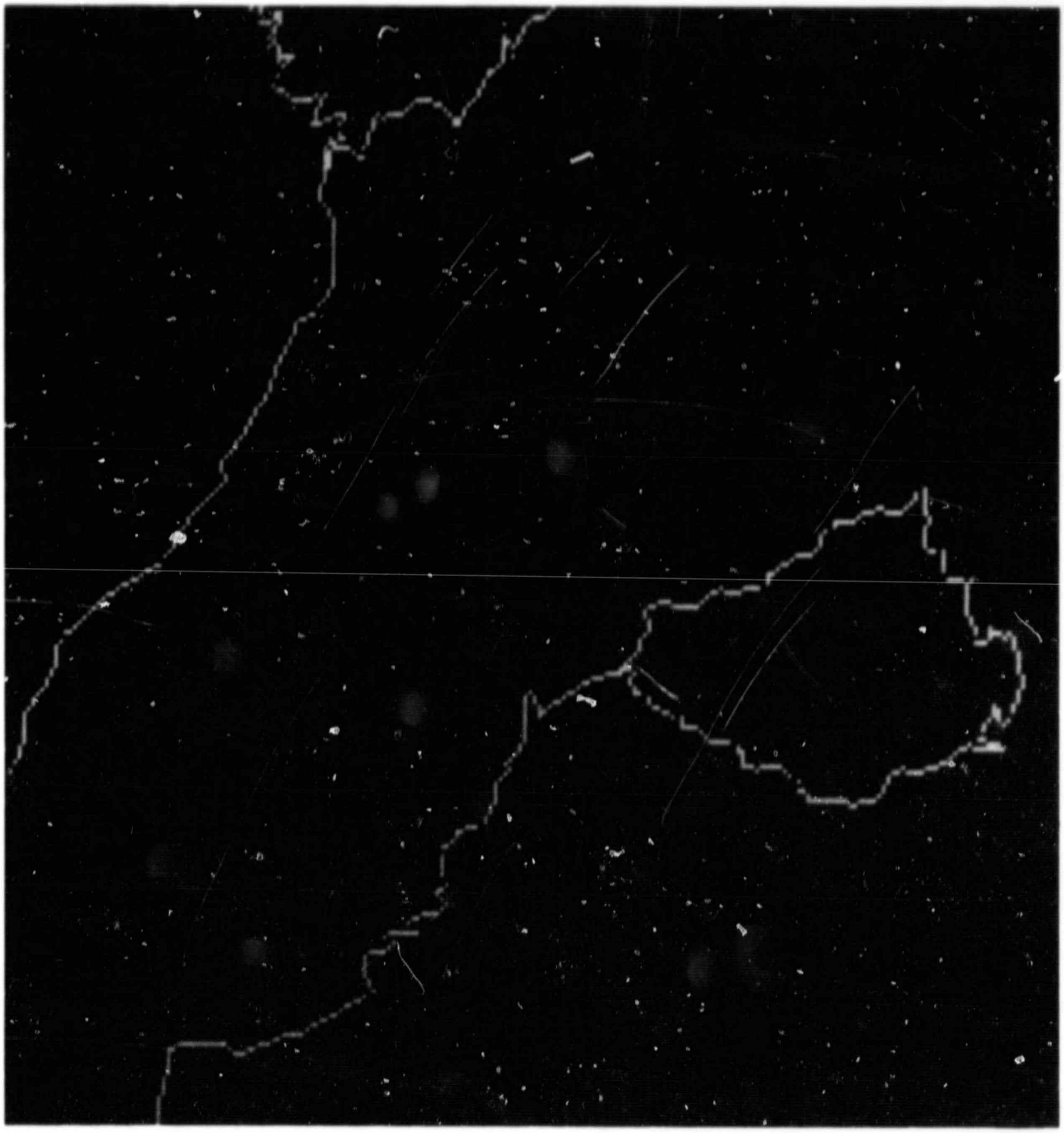

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Figure 23. Rampart Hills improved road network, based on 1962 USGS 7.5' quad map.

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Figure 24. Proximity to road for Rampart Hills. Each color from black to magenta represents a 200m interval.

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Figure 25. Location of all stands of upland conifer on 0-60% slopes within 1500m of the nearest improved road.

In addition to images and maps, numerical and tabular data can also be produced. As one demonstration of a capability currently available at ERIM, all upland conifer stands (contiguous cells of upland conifer) were located in one 1000 ha portion of the Rampart Hills Quad using the WHAMS (Roller, 1980) software package. The WHAMS package was used to compute and print out the location of each stand's center, its areal extent, its perimeter and shape factor, and the distance of the stand from the nearest road (see Table 8).

From Table 8 we can readily see that there are four upland conifer stands greater then 10 acres in size. However, only one of these stands (the 39.5 acre stand) is within a mile of an existing road.

4.4 RANGELAND SUITABILITY

Probably the greatest single requisite of good rangeland is availability of good forage. Other elements (e.g., water, salt, protection) are frequently furnished by livestock operators. Depending on the type and amount of forage, a given unit of terrain can support a certain number of animals for a given length of time (animal unit months, AUM). Assumed forage values for the land cover types in our land cover data layer are displayed for Rampart Hills Quadrangle in Figure 26.

The relative suitability for use by livestock is also affected by the slope of the terrain. According to San Juan National Forest Plans ("Determination of Lands Available, Capable and Suitable for Range Production, 1981), terrain with slope greater than 60% is considered unsuitable for livestock grazing. The allowable forage utilization on slopes from 30-60% is less than that on 0-30% slopes. The relative suitability for livestock grazing as a function of slope class that was assumed for this illustration is shown in Table 9.

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TABLE 8. TABULAR DATA FOR UPLAND CONIFER STANDS IN 1000 HA REGION IN NW CORNER OF RAMPART HILLS QUADRANGLE

AREA, PERIMETER AND SHAPE FACTOR STATISTICS FOR HABITAT UNIT: ONE

COVER CLASS ANALYZED = UPLAND CONIFER

TABULATION OF RECOGNIZED UPLAND CONIFER

SCAN LINE	POINT	AREA (HECTARES)	AREA (ACRES)	PERIMETER (METERS)	PERIMETER (FEET)	SHAPE FACTOR	CELLS TO ROAD	DISTANCE TO ROAD (meters)
38	4	6.50	16.06	1500	4921	1.66	57	2850
45	24	0.25	0.62	200	656	1.13	41	2050
48	28	0.50	1.24	300	984	1.20	39	1950
35	26	26.50	65.48	5300	17389	2.90	35	1750
42	53	16.00	39.54	3400	11155	2.40	15	750
49	14	2.00	4.94	700	2297	1.40	52	2600
53	13	0.25	0.62	200	656	1.13	55	2750
53	22	0.25	0.62	200	656	1.13	47	[illegible]
55	20	0.25	0.62	200	656	1.13	49	[illegible]
54	25	39.75	98.22	6550	21491	2.93	44	[illegible]
TOTALS:		92.25	227.95	18550	60863			

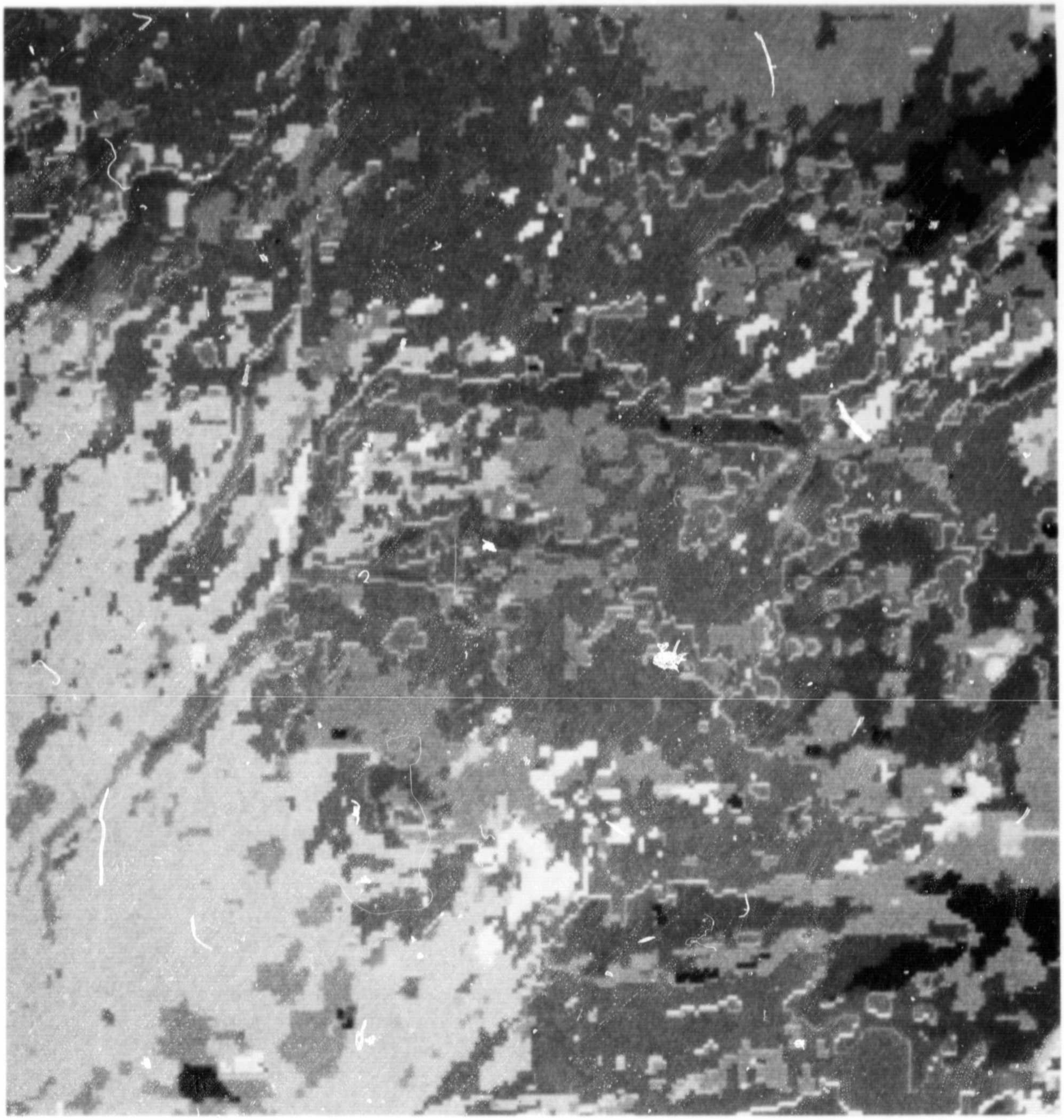

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Figure 26. Relative Suitability for Cover Type as Forage for Livestock.

2	UPLAND CONIFER	10	MEADOW
4	LOWLAND CONIFER	8	OPEN/POORLY STOCKED
6	ASPEN	0	BARE
2	MIXED FOREST	0	WATER
4	OAKBRUSH	0	CLOUD SHADOW

TABLE 9

RELATIVE SUITABILITY FOR LIVESTOCK GRAZING

Slope Interval (%)	Relative Suitability
0-30	2
31-60	1
61+	0 (unsuitable)

A point-specific measure of livestock grazing suitability as a function of forage value and slope was produced by combining the two components of suitability using the ERIM GIS capabilities. The results are presented in Figure 27.

4.5 WILDLIFE SUITABILITY

Suitability of an area for wildlife habitat is influenced by a great many factors. Among the important factors are the presence of suitable amounts and kinds of food and cover, plus certain specialized requirements such as the presence of water and the absence of inimical factors such as active logging or roads. Not only the presence, but also the spatial arrangement of the above factors can be quite important. For example, all necessary factors must occur within the home range of an individual animal. The more conveniently distributed these attributes are, the better that habitat. If high quality food occurs immediately adjacent to high quality cover, for example, that is preferable to them being far apart. Thus, juxtaposition, a factor that can be evaluated on a local (cell-by-cell) basis affects habitat quality. However, juxtaposition is not the only important factor, since only small, immobile animals are confined to a range as narrow as a specific edge (i.e., several meters). The patchiness (or interspersion) of the terrain can also affect habitat quality. Within the home range of an animal, the more places where suitable food and cover can be found nearby (but not necessarily adjacent), the more the terrain can be used by one or more animals. This assumption is consistent with the San Juan

Figure 27. Relative livestock grazing suitability as a function of cover type and slope.

National Forest management plan to manage for high values of Habitat Diversity Index. The relative proportion of food and cover in a unit of habitat also affects habitat quality. In addition, the home range of an individual of a particular species may be shared by other individuals of that species. Thus, habitat quality in terms of total carrying capacity is affected by the total amount of favorable characteristics which can be shared, not just what makes a good environment for a single individual of that species.

It can be noted from the above discussion that some of the factors that affect wildlife habitat quality are point (or nearly-point) attributes, whereas some of the factors can only be evaluated over some larger unit of terrain (e.g., home range). In this effort we attempt to address the use and usefulness of both kinds of attributes (point and non-point). Ultimately, it may be possible to combine both kinds of attributes into some integrated measure.

In the following material we present some examples of how the layers in the data base can be used to evaluate wildlife habitat quality. This material is presented for illustrative purposes, and addresses the issue of elk summer range habitat quality. No pretense is made, however, that we fully understand the components of good elk habitat or the interrelationships between those components. Nevertheless, attempts of this type to formalize and evaluate habitat attributes may facilitate the formulation of specific hypotheses regarding habitat quality which can be subsequently tested and evaluated.

4.5.1 POINT-SPECIFIC ATTRIBUTES

Two of the layers of the data base (land cover, roads) were evaluated with respect to one or more point-specific attributes. The formulation and utilization of those attributes is discussed in the following material.

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4.5.1.1 Food

One of the point-specific factors that is known to affect habitat quality is the value of the land cover type as food for the wildlife species of interest. The relative value of the land cover types as food which was assumed for this illustration is indicated in Figure 28. The resulting values of all 50 x 50 meter cells in the Rampart Hills Quadrangle were color-coded and are also displayed in Figure 28. The "cool" colors (blues and greens) represent low food values and the "warm" colors (orange and red) represent high food values.

4.5.1.2 Cover

Another point-specific factor that is known to affect wildlife habitat quality is the value of each cell as "cover" for the species of interest. The relative value for "cover" of each of the terrain types mapped which was assumed for this illustration is indicated in Figure 29 and is displayed using the same color code as for "food value" (Figure 28).

4.5.1.3 Juxtaposition

As mentioned earlier, the local relationships between various cover types can affect habitat quality. There are numerous ways that this juxtaposition of land cover types can be evaluated (e.g., Sattinger, et al., 1975; Roller, 1978). For this illustration we chose to use a method similar to that being used by Mead, et al (1981), in order to facilitate comparison of results based on different land cover layers. Specifically, each type of edge between the various land cover types was given a relative ranking (0-10). The matrix of weighting coefficients for all possible edges is indicated in Table 10. These values are based in part on discussions with SJNF personnel.* Note that whenever one cell is identical to an adjacent cell, the value as "edge" is assumed to

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*We especially wish to acknowledge the assistance of Dave Cook.

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Figure 28. Relative Suitability of Cover Type as Food for Elk.

3	UPLAND CONIFER	10	MEADOW
6	LOWLAND CONIFER	9	OPEN/POORLY STOCKED
8	ASPEN	1	BARE
4	MIXED FOREST	1	WATER
7	OAKBRUSH	5	CLOUD SHADOW

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Figure 29. Relative Suitability of Cover Type As "Cover" for Elk.

10	UPLAND CONIFER	1	MEADOW
7	LOWLAND CONIFER	2	OPEN/POORLY STOCKED
8	ASPEN	0	BARE
9	MIXED FOREST	0	WATER
4	OAKBRUSH	5	CLOUD SHADOW

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TABLE 10. ASSUMED RELATIVE VALUE OF LAND COVER EDGE TYPES FOR SUMMER ELK HABITAT

	Upland Conifer	Lowland Conifer	Aspen	Oakbrush	Meadow/Grass	Open	Mixed Hardwood/Conifer	Shadow	Bare	Water
Upland Conifer	0									
Lowland Conifer	2	0								
Aspen	6	6	0							
Oakbrush	4	4	4	0						
Meadow/Grass	3	8	10	3	0					
Open	7	8	8	3	2	0				
Mixed Hardwood/Conifer	2	3	5	5	9	8	0			
Shadow	5	5	5	5	5	5	5	5		
Bare	1	1	1	1	1	1	1	1	0	
Water	5	5	5	5	5	5	5	5	5	0

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be zero. We feel that zero weightings are necessary to preserve the concept of edge as a measure of diversity and ecological dissimilarity in which different life requirements are met by the different characteristics adjacent to each other at an edge. Where there is value in two adjacent cells having the same land cover type we feel that such information should be evaluated on the basis of the size of a homogeneous patch of terrain, or some other measure clearly distinct from an edge measure such as juxtaposition.

In a cellular grid of information, adjacent cells will represent more real linear edge than diagonal cells. Accordingly, we have given these two types of edges different weights. The weights used are 1.0 for adjacent cells and 0.5 for diagonal cells, which is consistent with Mead, et al (1981). The overall edge value of a given cell is then computed as the sum of all of the values of the adjacent and diagonal pixels. The resulting "juxtaposition" value for each cell was then compressed to values between 0 and 10 and is displayed in Figure 30 using the same color code as for "food" value and "cover" value.

4.5.1.4 Road Proximity

Another point-specific factor which is known to affect wildlife habitat quality is proximity to roads (e.g., Lyon, 1979). The data base layer containing presence or absence of roads was modified to produce a layer of road proximity information. Specifically, a special-purpose cytocomputer™ developed at ERIM was used to calculate the distance of any cell to all cells containing road, and then the minimum distance was stored in that cell. This procedure was repeated for each cell, until all cells were assigned values of distance to nearest road.

4.5.1.5 Road Suitability

Since the item of particular interest for this illustration was the effect of roads on elk habitat quality, the road distance data layer was further modified to indicate relative effect on elk habitat quality,

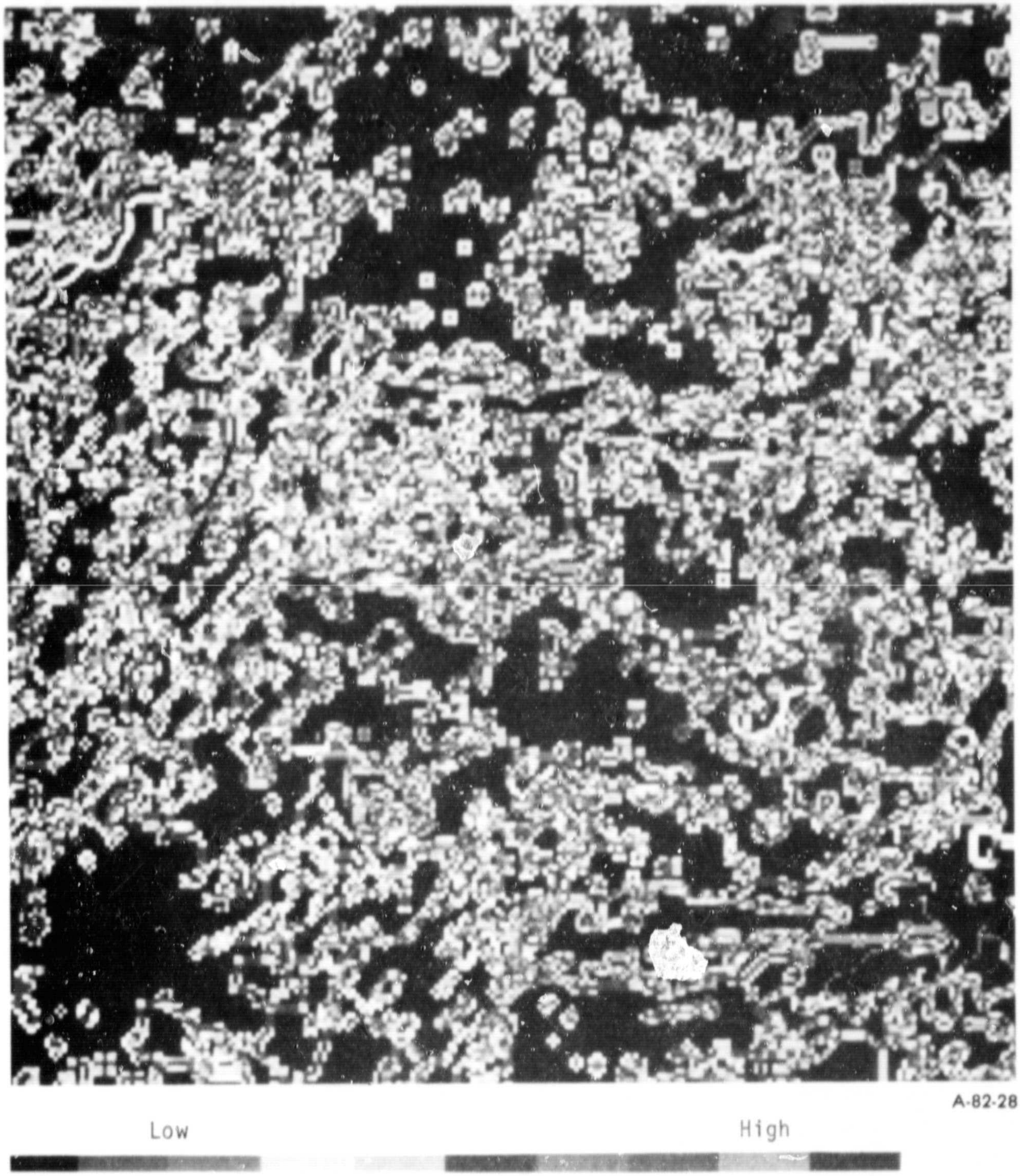

Figure 30. Relative juxtaposition value for cover type layer of data base.

based on data from Lyon (1979). The road distance layer was modified into 10 road suitability classes which are displayed in Figure 31. Although the effect of roads on habitat quality is known to be dependent on the specific land cover type present, as well as the surrounding land cover type, that additional complexity was avoided for this illustration.

4.5.2 AREA-SPECIFIC ATTRIBUTES

Area-specific measures similar to some of the point specific measures will also be prepared, but they are not available at this time. Some of the related area-specific and point-specific measures are listed in Table 11.

TABLE 11

RELATED AREA-SPECIFIC AND POINT-SPECIFIC MEASURES

Area Specific	Point Specific
Average/Total Food Value	Food Value
Average/Total Cover Value	Cover Value
Average/Total Weighted Edge	Juxtaposition
Road Density	Distance to Road
Average Slope	Slope
Average Elevation	Elevation

4.5.2.1 Habitat Diversity Index (HDI)

Another area-specific factor is the Habitat Diversity Index which is being examined by San Juan National Forest personnel ("Wildlife Process Criteria," 1981). We have attempted to produce a Habitat Diversity Index for a single 1000 ha section of the Rampart Hills Quadrangle (specifically the northwest corner). The Habitat Diversity Index is the cumulative score of several individual measures, namely: (1) inherent diversity, (2) number of feature types, (3) average size of feature types, and (4) mixture of age (size) classes.

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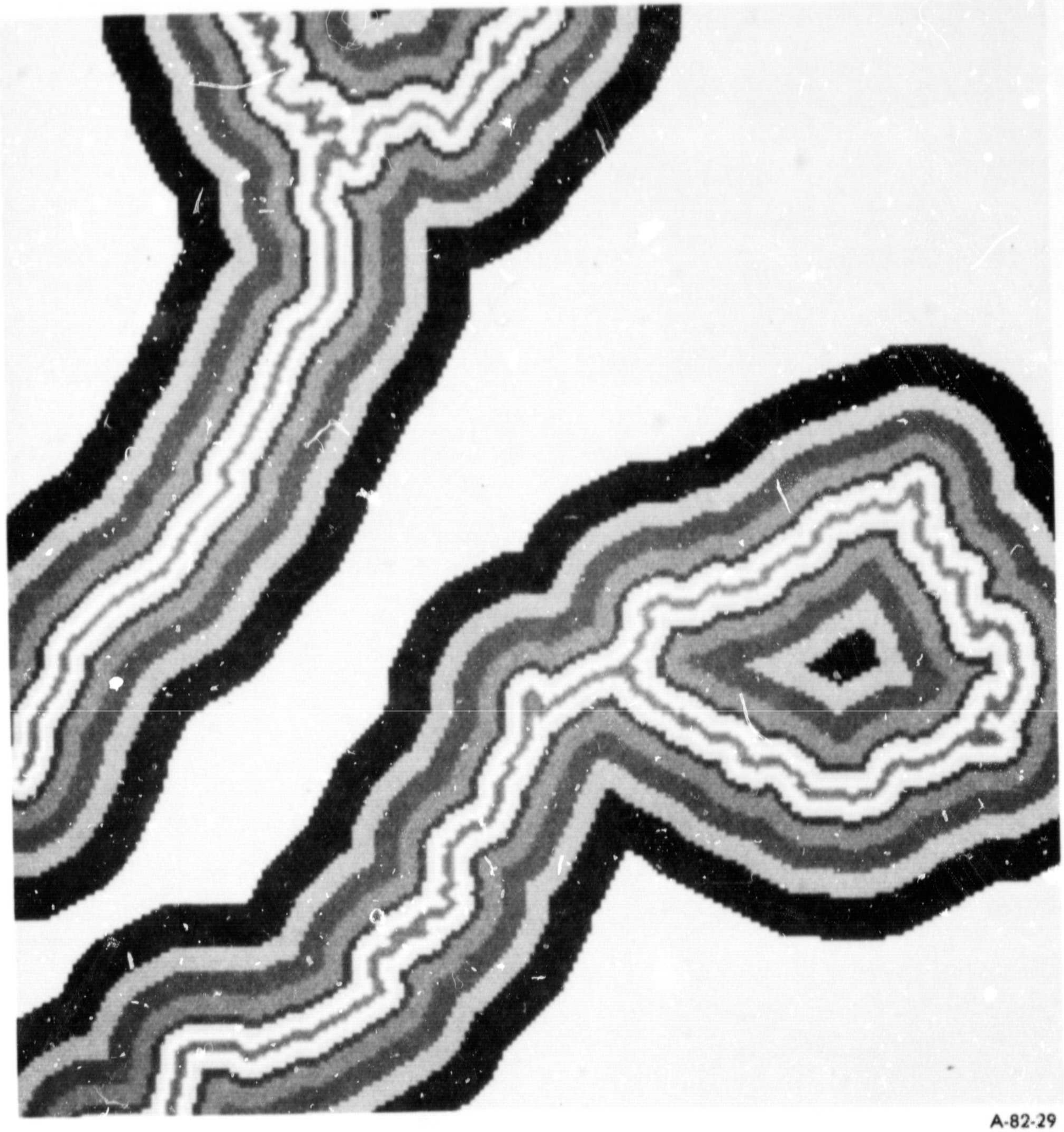

Figure 31. Relative Suitability of Elk Habitat as Influenced by Proximity to Road.

1	≤50m	6	351-500m
2	51-100m	7	501-700m
3	101-150m	8	701-1000m
4	151-250m	9	1001-1500m
5	251-350m	10	>1500m

The Habitat Diversity Index (HDI) cannot be exactly duplicated with our land cover data layer since the categories mapped do not contain sufficient detail. However, a reasonable approximation can be obtained.

The basic information with which an HDI was computed was obtained from a WHAMS analysis of all cells in the chosen 1000 ha area. WHAMS provides summary information on HDI-related parameters (e.g., see Table 11).

4.5.2.1.1. Inherent Diversity

Inherent Diversity is based on the proportion of forested to non-forested land. We assumed that forested land consisted of all areas identified as upland conifer, lowland conifer, aspen, or mixed. Everything else except water was considered non-forest. The resulting proportion of forest to non-forest was determined from Table 12 to be 82%:18%. Per HDI procedures this was given a score of 2.

4.5.2.1.2 Feature Abundance

A feature type abundance score was computed by determining the number of land cover types present in the 1000 ha test area and normalizing this value by multiplying by the ratio of number of possible cover types in our data base to the nominal optimal number based on the SJNF data base. With HDI procedures and using Table 12 we arrived at a score of 4.

We wonder whether this measure might not be more meaningful if it were related to cover type identity, as well as abundance. For example, it might be helpful to consider the abundance of forest and non-forest categories separately.

4.5.2.1.3 Feature Size

A feature size score was also computed using WHAMS output tables similar to that shown in Table 8 (section 4.3). The scores for each

TABLE 12. AREAL EXTENT OF COVER TYPES PRESENT IN 1000 HA TEST AREA

COVER CLASS STATISTICS FOR HABITAT UNIT: ONE

LENGTH OF HORIZONTAL PIXEL EDGE = 50.00 METERS
LENGTH OF VERTICAL PIXEL EDGE = 50.00 METERS
MAXIMUM CLASS CODE ENCOUNTERED DURING STATISTICS CALCULATION = 7
NUMBER OF UNCOUNTABLE PIXELS DUE TO INVALID CLASS CODES = 0
TOTAL NUMBER OF PIXELS USED IN CALCULATIONS = 3808

CLASS CODE	NAME	AREA (HECTARES)	AREA (ACRES)	RELATIVE ABUNDANCE
1	UPLAND CONIFER	93.500	231.038	9.821
2	LOW CONIFER	29.750	73.512	3.125
3	ASPEN	499.250	1233.646	52.442
4	OAK	83.500	206.328	8.771
5	MEADOW	0.0	0.0	0.0
6	OPEN	86.250	213.124	9.060
7	MIXED	159.750	394.742	16.780
	TOTALS	952.000	2352.392	100.000

cover type based on stands >5 acres in size are shown in Table 13. Based on this approach the "average score" is 4.

It might be helpful to consider the median size, rather than the mean, because the median may be a better description of "most common" conditions, especially when there are a few very large (or very small) stands. For example, for all of the above cover types the average size stand is 66 acres, but one stand is over 900 acres. The median value for the same data is less than 25 acres.

TABLE 13

FEATURE SIZE SCORES BY COVER TYPE FOR HDI

Cover Type	Average Size	Score
Upland Conifer	55	5
Lowland Conifer	29	4
Aspen	205	1
Oak	23	4*
Meadow	---	---
Open	21	4*
Mixed	48	5
	Average Score =	4

*Assumed value for undefined size class

It might also be helpful to consider the desirability of a certain size stand to be type-dependent. For example, small patches of meadows or open areas may be most desirable, whereas large patches of forest may be most desirable.

4.5.2.1.4 Combined Measure

The above separate measures were combined to produce a Habitat Diversity Index, as shown in Table 14. Since age-class could not be determined from our data, the total score was pro-rated on the basis of three measures. The resulting HDI of 15 is considered by SJNF to be "high habitat diversity; actions necessary to maintain should be scheduled in future decades."

TABLE 14

HABITAT DIVERSITY INDEX DATA

Factor	Score
1. Inherent Diversity	2
2. Feature Abundance	4
3. Average Size	5
4. Age	--

HDI Rating = 4/3 x 11 = 15 = High HDI

4.5.3 DISCUSSION OF ATTRIBUTES

It is suggested that both the point-specific and area-specific attributes be evaluated by San Juan National Forest personnel. The evaluation probably should be based on how well any of the attributes describe true habitat quality, based on both theoretical considerations and empirical evidence of actual conditions on the Rampart Hills Quadrangle. The relative utility of point-specific and area-specific attributes should be addressed.

4.5.3.1 Interaction of Factors

In the initial phases of evaluation of wildlife habitat, it seems appropriate to examine various attributes individually. However, it seems likely that no single attribute will be found to be sufficient to completely characterize wildlife habitat quality. It seems likely that various combinations of attributes will be necessary for full characterization to be achieved. The way these attributes relate to each other is presently not well understood. Previous attempts to produce integrated measures of habitat quality based on aggregation of several components (e.g., Sattinger, et al., 1975) have proved to be somewhat inconclusive. Nevertheless, integrated measures may eventually prove to be valid and useful, so an illustration of one possible way of combining attributes is presented here. The goal of this illustration is to produce an integrated measure of habitat quality based on all of the individual point-specific attributes previously generated, namely (1) food value; (2) cover value; (3) juxtaposition; and (4) road-effect.

For the purposes of this illustration we presume that food and cover have approximately equal importance in their effect on habitat quality and that juxtaposition is a somewhat less important factor for a mobile animal such as elk. Based on the above considerations we prepared a measure of the overall effects of the individual land cover attributes, and we call it Integrated Habitat Quality Index, IHQI.

$$\text{IHQI} = \text{Food Value} + \text{Cover Value} + .5^{*}\ \text{Juxtaposition Value}$$

The relative values of IHQI for every cell in the data base were then scaled from 0-10, and are displayed in Figure 32.

Since we know that point-specific habitat quality is affected by proximity to road, we subsequently modified IHQI on the basis of the file containing Road-Suitability (RS) rankings (4.5.1.5). The modification was multiplicative, so that all IHQI values closer than 1500 meters to the nearest road (RS < 10) were reduced. The resulting Road-Suitability-modified IHQI (RSIHQI) was rescaled from 0-10 and is displayed in Figure 33.

4.6 FUTURE PLANS

Future plans include assessments of the illustrative products generated to date. Attention will be given to possible improvement in basic attributes through improved weighting coefficients and the like. Additional attention will be given to combining various attributes into integrated measures. Additional attributes (e.g., soils, elevation, etc) will be added to the analysis. Area-specific analogues of point-specific suitability measures will be generated.

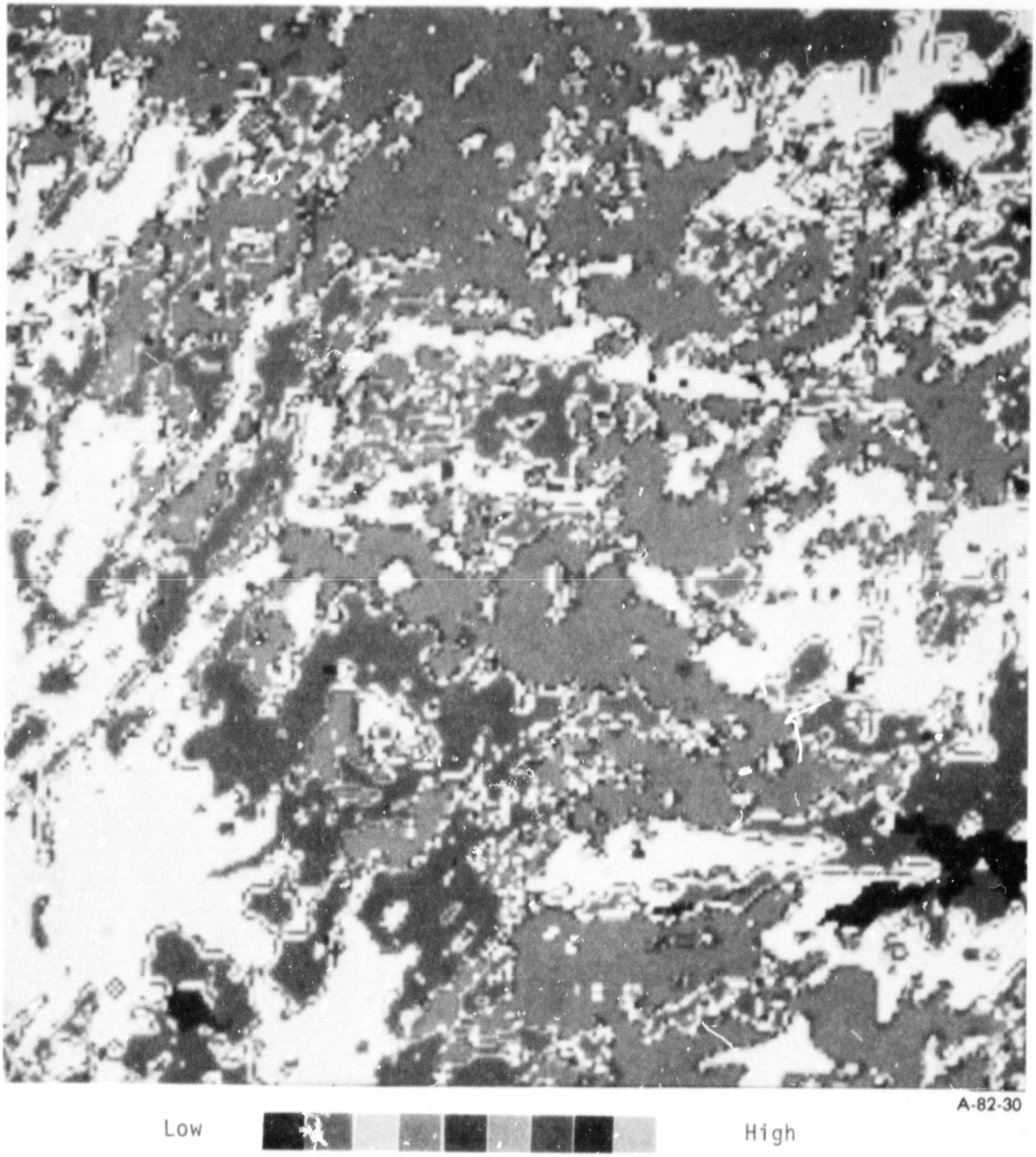

Figure 32. Integrated Habitat Quality Index (IHQI).

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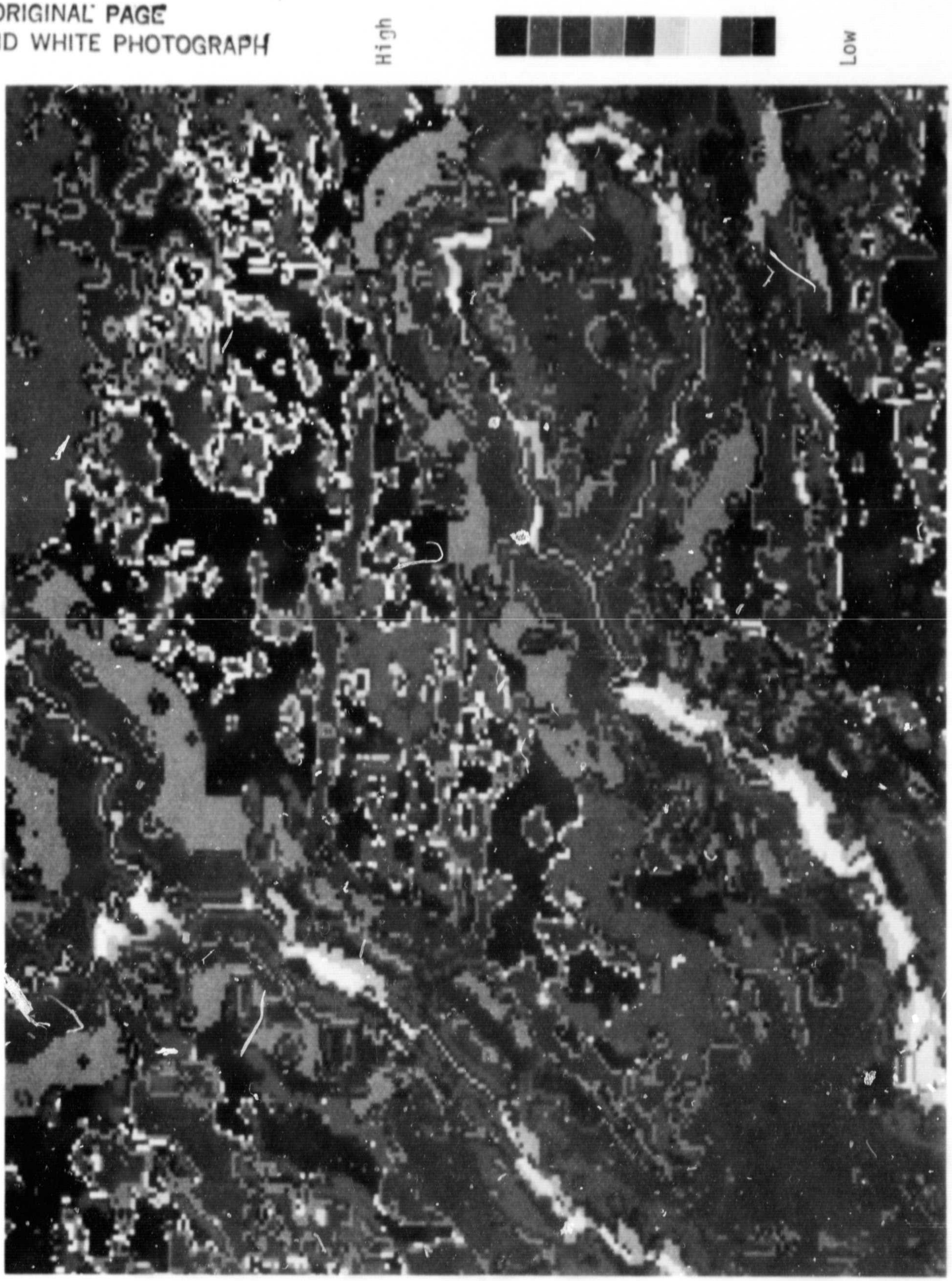

Figure 33. Road influenced Integrated Habitat Quality Index (IHQI).

It is envisioned that eventually it will be desirable to express measures of suitability for various uses in comparable terms such as monetary value. For example, habitat quality may be related to carrying capacity in terms of numbers of animals that could be supported. The carrying capacity might then be related to monetary value. Similarly, grazing potential might be related to AUM's and associated monetary value, and timber potential might be related to board ft/year which could be related to monetary value. When evaluated on the basis of similar units of measure (e.g., money), relative site suitability for various uses can be compared, and optimal multiple use strategies can be formulated.

5

CONCLUSIONS AND RECOMMENDATIONS

5.1 GEOMETRIC CORRECTION

The Forest Service has requirements to geometrically correct and register multiple Landsat scenes to a UTM geometric grid. This grid is necessary to permit overlay of a great amount of information now in map overlay form in a digital data base. Forest Service requirements appear to be unique and different from those of other USDA agencies (e.g., CCAD) and from those of NASA. Although there is a stated policy to deliver Landsat data in UTM projection upon retrospective order from the EROS Data Center, there is currently no support for this capability.

Because of uncertainties in the availability and timeliness of data in the required projection, we recommend that the Forest Service pursue installation and test of the ERIM software package on an appropriate Forest Service computer, while relying on ERIM to provide registered data sets for AgRISTARS effort. The ERIM software package can produce restored, geometrically corrected data in UTM projection with high geometric and radiometric fidelity. In parallel with the installation, checkout, and operation of the ERIM package, the Forest Service should continue to enunciate its geometric correction requirements to NASA, NOAA, and the EROS Data Center in hopes that the production of data in the appropriate format might become available from future versions of the Landsat or Civil Land Remote Sensing System.

5.2 CHANGE DETECTION

Although some initial recommendations have been made regarding routine procedures for running BLOB/CVA, considerably more work must be done. It seems probable, however, that routine procedures will, at best, only be able to define "ball-park" figures for setting parameters, and that considerable subjectivity may remain for the conceivable future.

Since changes on the San Juan National Forest tend to be slow, have small areal extent, and have subtle spectral manifestations, we do not believe that change detection will be as important or as successful on the current data set as it was on the South Carolina data set. Because of that situation we recommend that change detection be given low priority in the San Juan National Forest.

5.3 RESOURCE SUITABILITY

We believe that some of the capabilities for assessing multiresource suitability which are described in this report can potentially be useful to San Juan National Forest personnel. We recommend that future efforts by ERIM be designed to be as responsive to San Juan National Forerst issues as possible. In order to ensure this, we recommend that a continuing dialogue between ERIM and key San Juan National Forest personnel be maintained.

REFERENCES

Andrews, F. and R.C. Messenger, 1973, "Multivariate Nominal Scale Analysis," Institute for Social Research, The University of Michigan, Ann Arbor, Michigan.

Clark, C.A., 1981, "Use and Applicability of the Vegetation Component of the National Site Classification System," AgRISTARS Report JSC-17122. Lockheed, Inc., 1830 NASA Road 1, Houston, TX, 77058.

Colwell, J., G. Davis, and F. Thomson, 1980, "Detection and Measurement of Changes in the Production and Quality of Renewable Resources," ERIM Report 145300-4-F.

Colwell, J., 1981, "Landsat Feature Enhancement," Proceedings of 15th International Symposium on Remote Sensing of Environment.

Colwell, J. and F.P. Weber, 1981, "Forest Change Detection," Proceedings of 15th International Symposium on Remote Sensing of Environment.

Crouse, Ken, 1981, EROS Data Center, Sioux Falls, South Dakota, private communication.

EROS Data Center, 1978 "Landsat Data Users Handbook."

Graham, R. and J. Tonn, 1980, "Case Study: Growth and Development of Forest Stands in the Northern Rocky Mountains." USDA Forest Service, Research Paper INT-255.

Grebowsky, Gerald, 1981, NASA/Goddard Space Flight Center, Greenbelt, Maryland, private communication.

Hoffer, R., M. Fleming, L. Bartolucci, S. Davis, and R. Nelson, 1979, "Digital Prorcessing of Landsat MSS and Topographic Data to Improve Capabilities for Computerized Mapping of Forest Cover Types," LARS Technical Report 011579.

Holmgren, R., 1973, "The Desert Experimental range: description, history, and program," Arid Shrublands - Proceeding of the Third Workshop of the United States/Australia Rangelands Panel, Tucson, AZ.

Kauth, R.J., and G.S. Thomas, 1976, "The Tasseled-Cap -- A Graphic Description of the Spectral-Temporal Development of Agricultural Crops as Seen by Landsat," Machine Processing of Remotely Sensed Data, Symposium Proceedings, LARS/Purdue University, W. Lafayette, Indiana.

Kauth, R.J., A.P. Pentland, and G.S. Thomas, 1977, "BLOB, An Unsupervised Clustering Approach to Spatial Preprocessing of MSS Imagery," Eleventh International Symposium on Remote Sensing of Environment, Environmental Research Institute of Michigan, Ann Arbor, Michigan, Vol. 2, pp. 1309-1317.

Lyon, L. Jack, 1979, "Habitat Effectiveness for Elk as Influenced by Roads and Cover," Journal of Forestry, Vol. 77, No. 10.

Malila, W., 1980, "Change Vector Analysis: An Approach for Detecting Forest Changes with Landsat," Proceedings, Purdue:LARS 1980 Machine Processing of Remotely Sensed Data Symposium.

Mazade, A.V., et al., 1981, "Ten Ecosystem Study," NASA Report #9-15800. Lockheed Engineering and Management Services Co., Inc., Houston, Texas.

Mead, R., T. Sharik, S. Prisley, and J. Heinen, 1981, "A Computerized Spatial Analysis System for Assessing Wildlife Habitat from Vegetation Maps," Technical Papers from 47th Annual Meeting American Society of Photogrammetry, Washington, D.C.

Peavey, Bernard, 1981, NASA/Goddard Space Flight Center, Greenbelt, Maryland, private communication.

Pfister, R., 1975, "America's Renewable Resource Potential - 1975: The Turning Point," Proc. 1975 National Conference Soc. A. For., 1976: 312-325.

Roller, N., 1978, "Quantitative Evaluation of Deer Habitat," Proceedings EROS Pecora IV Symposium, Sioux Falls, South Dakota.

Roller, N., 1979, "Description of ERIM Wildlife Habitat Evaluation Services," ERIM, Ann Arbor, Michigan.

San Juan National Forest, 1981, "Wildlife Process Criteria," (7/12/81). Appendix M of San Juan National Forest Document.

San Juan National Forest, 1981, "Determination of Lands Available, Capable and Suitable for Range Productions," Section Vi of San Juan National Forest Document.

Sattinger, J., R. Dillman, and N. Roller, 1975, "Analysis of Recreational Land and Open Space Using ERTS-1 Data," Report No. 193300-60-F, Environmental Research Institute of Michigan, Ann Arrbor.

Thomson, F., C. Wilson, F. Sadowski, W. Malila, R. Dye, 1980, Application and Further Development of Remote Sensing Techniques for Forest Management, ERIM Report 138400-6-F.

Ward, J., 1981, "Data Base Development from Large Format Photography for the San Juan 1980 Multiresource/Remote Sensing Project: Work Plan, LEMSCO-16927.

Wilson, Charles L., 1980, Landsat Derived Maps of Poorly Mapped Areas, paper presented at Harvard Computer Graphics Week '80, Cambridge, Massachusetts.

APPENDIX I

MULTIVARIATE ANALYSIS AS AN AID IN CLASSIFICATION

Landsat MSS data has proven to be an effective system for classifying large land areas into several broadly defined cover types. For example, a recent study shows classification accuracies of 99% for hardwood, conifer, tundra, and water categories in Alaska (Mazade, et al., 1981). Landsat classification accuracy falls off rapidly when one tries to distinguish different species or species groups of hardwood and conifer. For this level of classification, one has to utilize ancillary data (i.e., elevation, soil type, aspect, etc.), in order to attain acceptable levels of accuracy. The cover type classification for this project would have been seriously flawed without the stratification between conifer types which was made possible with DMA elevation data.

A multivariate additive model may prove to be useful in classification with ancillary data (Andrews and Messenger, 1973). Multivariate nominal analysis (MNA) was developed for applications in the social and psychological sciences for use on categorical data. It had never been tested with biological or ecological data until the model was used this summer with data from Idaho. The test used five independent variables - geology, elevation, landform, soil type, and aspect - to predict which of three species (fir, hemlock, cedar) would most likely occupy a site given a certain set of the variables. Although a detailed analysis is not available at this time, a considerable gain in accuracy of prediction is achieved when this set of variables is used to predict cover type. Further work is envisioned to incorporate Landsat MSS data on a numerical scale with the categorical scale levels of these data types.

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APPENDIX II

OBSERVATIONS ON LAND SUITABILITY ISSUES

Site parameters such as soils, topography (slope/aspect), elevation, and current vegetation probably can be mapped reasonably objectively by field procedures, and there is probably a reasonable amount of agreement that they are important fundamental attributes affecting site suitability. Therefore, such parameters almost certainly should be included in a data base designed to assess site suitability.

Some other attributes where the situation is less clear should be subjected to intensive examination before a decision is made to include them in a data base. One such attribute is "climax" or "potential" vegetation or "habitat type" (all three terms are sometimes used more or less interchangeably). Whenever the "climax" vegetation is not currently present on a site, the site label is, by definition, inferential or derived. It seems probable that some broad level of general categorization of large areas with uniform climate is possible. For example, the Great Plains as a region might be called Grassland and the humid Tropics might be called forest. However, there is reason to doubt that such labels can be objectively determined in the field on a site specific basis, at least for some kinds of environments.

For example, Holmgren (1973) found that for portions of the Great Basin "some communities, considered to be climax or near climax, have arrived at their condition of uniform composition from a number of simultaneously differing earlier stages." Holmgren discovered that "the reverse has also taken place: a single community in a lower stage of succession can progress to a variety of communities at higher stages. These observations suggest that the unambiguous prediction of "climax" vegetation type from analysis of "non-climax" vegetation is not possible, at least for some environments.

Lacate (1969) notes that in Canada "It will not be possible in all areas to work out successional relationships." Clark (1981) notes that in the Southeastern United States "it seems questionable whether or not potential natural vegetation can ever be correctly determined." Serious consideration should be given to whether a category for which information may never be available for entire regions of the United States should be a fundamental component of a data base on site-specific bases.

Another consideration in the utilization of "potential" vegetation labels is the utility of such information. It has been postulated by some that classification of "potential" vegetation could furnish the basis for an assessment of the value of a site for producing a certain resource relative to other sites, as well as an assessment of the relative utility of producing various alternative resources on a single site. For example, it has been postulated that all "sites within a habitat [climax] type have essentially equivalent biotic potential," in which there is "a relatively narrow range of capability to provide any specified resource." (Pfister, 1975).

However, there is some evidence to suggest this range is not so "narrow" in some cases. For example, Graham and Tonn (1980) have shown a "wide range of growth on the same habitat type." Age-adjusted diameter growth means were found to vary by a factor of 4 within a single habitat type. Pfister (1975) presents data showing variation in "yield capability" of over 100% in one climax type, spanning the range from the "low" yield capability class to the "high" yield capability class of all climax types in the area.

Despite the apparent problems in utilization of "climax" or "habitat type" labels, there is a strong and understandable desire on the part of many land managers to be able to characterize a site in terms of its potential. We do not have a fully satisfactory solution to this situation. However, it does seem to us that some approaches are preferable to others.

If there really are compelling reasons for assigning potential vegetation labels to terrain units, certain safeguards should be built in. The "potential vegetation" label that is produced should be clearly understood to be an infered parameter, rather than a fundamental, objectively measurable component of the data base. The potential vegetation label should then be derived from a clearly and unambiguously stated set of relationships between all relevant components of the data base. Thus all useful information, not just current vegetation information, will be used to infer the appropriate potential vegetation label in a consistent manner.

A different approach (which we greatly prefer) is to make assessments of fundamental site potential without regard to the assumed potential vegetation and the uncertainty associated with that label. For example, it may be possible to project what the fundamental relative productivity of various sites are with respect to each other regardless of what the true potential species composition might be. This alternative removes the uncertainty associated with the potential vegetation label. However, it also adds another form of uncertainty in that productivity and other factors are not in actuality completely independent of species composition. Presumably, current site potential productivity could be assessed on the basis of fundamental potential and current vegetation.

If the accuracy of the above predictions of site potential could be demonstrated through future experiments, useful information would be available to land managers. If, on the other hand, future experiments showed different resulting "potential" than had been predicted, the newly discovered relationships could be used to operate on the same data base of fundamental properties to produce new, more accurate inferences of "potential." In the interim, the "potential" labels could be clearly seen to be inferential, and the exact way in which the inference was made could be seen by all. This would not be the case if labels had initially been assigned on a somewhat subjective basis, that might differ from one "mapper" to another.

APPENDIX III

SOFTWARE DEVELOPMENT

Another objective of the change detection task was to make the change detection software understandable, user-friendly, and compatible with the Remote Analysis Station (RAS). Progress to date for BLOB software and CVA software are described in the following material.

BLOB SOFTWARE DESCRIPTION

The program SUPERB is called to run the BLOB algorithm, and the operator responds to the program's prompts:

```
> RUN SUPERB
SUPERB (BLOB) VERS 1.0
ENTER FILE NAME OF INPUT FILE ? TEST
ENTER DRIVE ? 1
ENTER FILE NAME OF OUTPUT FILE ? TESTCVA
ENTER DRIVE ? 1
ENTER NUMBER OF CHANNELS TO PROCESS ? 4
ENTER   4 CHANNELS TO PROCESS ?
1,2,3,4,
DO YOU WISH TO SCREEN DATA (Y/N)  ?N
ENTER BLOB LOGIC METHOD ? 1
-> COMBINED SPECTRAL-SPATIAL DISTANCE METHOD ACTIVE <-
ENTER TAU1  &  TAU2 VALUE ? 35.,0.
ENTER VARL,VARP ? 169.,169.,
ENTER   4 SPECTRAL VARIANCES ? 25.,16.,25.,16.,
BLOB ID OUTPUT CHANNELS ARE     5     6
BLOB INPUT CHANNELS ARE       1     2     3     4
FILE CONTAINS    10 PIXELS,    10 LINES,     4 CHANNELS
  BLOB LINE=   10
-> SUPERB IS DONE <
```

The input file "TEST" in this case contains the Brightness and Greenness for 1978 and 1980 in channels 1,2,3, and 4. The BLOB logic method used is the combined spectral/spatial distance method (#1); options 2 and 3 are the separate spectral/spatial and separate date logics. Option 1 has only one value for TAU, which is entered along with a zero. VARL and VARP are the spatial line and point weights, while the four spectral variances are the weights for Brightness and Greenness for the two dates. The BLOB identification number for each pixel is stored in channels 5 and 6 of the output file "TESTCVA", along with Brightness and Greenness in channels 1-4.

CVA SOFTWARE DESCRIPTION

The following describes the program input, and the expected data is given in parenthesis.

```
> RUN CVAB
CHANGE VECTOR ANALYSIS "BLOB" VERS1.0
ENTER FILE NAME FOR INPUT ? TESTCVA                          (ALPHA NUMERIC)
ENTER DRIVE ? 1                                                   (INTEGER)
ENTER FILE NAME FOR OUTPUT FILE ? TESTNEW                    (ALPHA NUMERIC)
ENTER DRIVE ? 1                                                   (INTEGER)
ENTER FILE NAME OF LOOKUP TABLE ? FILL.001                   (ALPHA NUMERIC)
ENTER CVA METHOD ? 1                                              (INTEGER)
> MAGNITUDE OF CHANGE STRATEGY ACTIVE <
ENTER THRESHOLDS FOR MAG ? 20., 999.                                 (REAL)
ENTER GREENNESS CHANNEL FOR STRATA CODE (FOREST) ? 2              (INTEGER)
ENTER BRIGHTNESS CHANNEL FOR STRATA CODE (NONFOREST) ? 1          (INTEGER)
ENTER NUMBER OF STRATA 1 ANGLE INTERVALS (FOREST) ? 2             (INTEGER)
ENTER NUMBER OF STRATA 2 ANGLE INTERVALS (NONFOREST) ? 2          (INTEGER)
ENTER 2 (FOREST) ANGLE INTERVALS ? 0,20,40,360                    (INTEGER)
ENTER 2 (NONFOREST) ANGLE INTERVALS ? 0,10,40,60                  (INTEGER)
ENTER 2 ANGLE CODES FOR (FOREST) ? 1,2                            (INTEGER)
ENTER 2 ANGLE CODES FOR (NONFOREST) ? 4,5                         (INTEGER)
ENTER UNDEFINED CODES FOR FOREST,NONFOREST ? 3,7                  (INTEGER)
ENTER SCALE FACTOR FOR GREENNESS AND BRIGHTNESS CHANNELS ? 1.0,1.0
    (REAL)
```

The input file "TESTCVA" contains four channels of Brightness and Greenness data as well as blob informatiton. The file "FILL.001" contains the forest/non-forest stratification look-up table, in which a decision boundary has been constructed in Brightness/Greenness space. Two CVA methods are available (as described in section 3.1.3) - #1 refers to the magnitude of change strategy while #2 is the proportional change logic.

The operator then proceeds to enter the CVA parameters. Magnitude of change thresholds require a lower and upper boundary. Since there are four channels containing Brightness and Greenness information, the user specifies which two channels are to be used in the forest/non-forest stratification. The number of CVA angle intervals for each stratum and their limits are required. The values for the angle intervals refer to a circular plot, with 0° at the three o'clock position, increasing in value counter clockwise to 360°. A number code is assigned to each interval for each stratum, as well as to any undefined angular regions within each stratum. If necessary, scale factors for the Brightness and Greenness channels may then be entered to equalize the range of values in each channel so that a circular, and not elliptical, plot may be used.

In the example above channel 2 (Greenness 1978) of "TESTCVA" is used in the forest stratification, while channel 1 (Brightness 1978) is used for non-forest. There are two angle intervals defined for each stratum: 0-20° and 40-360° for forest; 0-10° and 40-60° for non-forest. These angles are assigned codes 1,2,4, and 5 respectively, and might refer to deforestation, reforestation, non-forest loss of vegetation, and non-forest gain of vegetation. Any angle not covered under these categories would be assigned a 3 if in the forest stratum, or a 7 if non-forest. These six numerical codes could then be assigned a color to produce a CVA categorized image, or tabulated for areal statistics.

* U.S. GOVERNMENT PRINTING OFFICE: 1982—580-011/1200